Syllabus: Artificial Intelligence

Module-I: (12 hours)

INTRODUCTION –The Foundations of Artificial Intelligence; - INTELLIGENT AGENTS – Agents and Environments, Good Behaviour: The Concept of Rationality, the Nature of Environments, the Structure of Agents, SOLVING PROBLEMS BY SEARCH – Problem-Solving Agents, Formulating problems, Searching for Solutions, Uninformed Search Strategies, Breadth-first search, Depth-first search, Searching with Partial Information, Informed (Heuristic) Search Strategies, Greedy best-first search, A* Search, CSP, Means-End-Analysis.

Module-II: (12 hours)

ADVERSARIAL SEARCH – Games, The Mini-Max algorithm, optimal decisions in multiplayer games, Alpha-Beta Pruning, Evaluation functions, Cutting off search, LOGICAL AGENTS – Knowledge-Based agents, Logic, Propositional Logic, Reasoning Patterns in Propositional Logic, Resolution, Forward and Backward chaining - FIRST ORDER LOGIC – Syntax and Semantics of First-Order Logic, Using First-Order Logic , Knowledge Engineering in First-Order Logic - INFERENCE IN FIRST ORDER LOGIC – Propositional vs. First-Order Inference, Unification and Lifting, Forward Chaining, Backward Chaining, Resolution

Module-III: (6 hours)

UNCERTAINTY – Acting under Uncertainty, Basic Probability Notation, The Axioms of Probability, Inference Using Full Joint Distributions, Independence, Bayes' Rule and its Use, PROBABILISTIC REASONING – Representing Knowledge in an Uncertain Domain, The Semantics of Bayesian Networks, Efficient Representation of Conditional Distribution, Exact Inference in Bayesian Networks, Approximate Inference in Bayesian Networks

Module-IV: (10 hours)

LEARNING METHODS – Statistical Learning, Learning with Complete Data, Learning with Hidden Variables, Rote Learning, Learning by Taking Advice, Learning in Problem-solving, learning from Examples: Induction, Explanation-based Learning, Discovery, Analogy, Formal Learning Theory, Neural Net Learning and Genetic Learning. Expert Systems: Representing and Using Domain Knowledge, Expert System Shells, Explanation, Knowledge Acquisition.

What is Intelligence?

The ability of a system to calculate, reason, perceive relationships and analogies, learn from experience, store and retrieve information from memory, solve problems, comprehend complex ideas, use natural language fluently, classify, generalize, and adapt new situations.

Types of Intelligence

As described by Howard Gardner, an American developmental psychologist, the Intelligence comes in multifold –

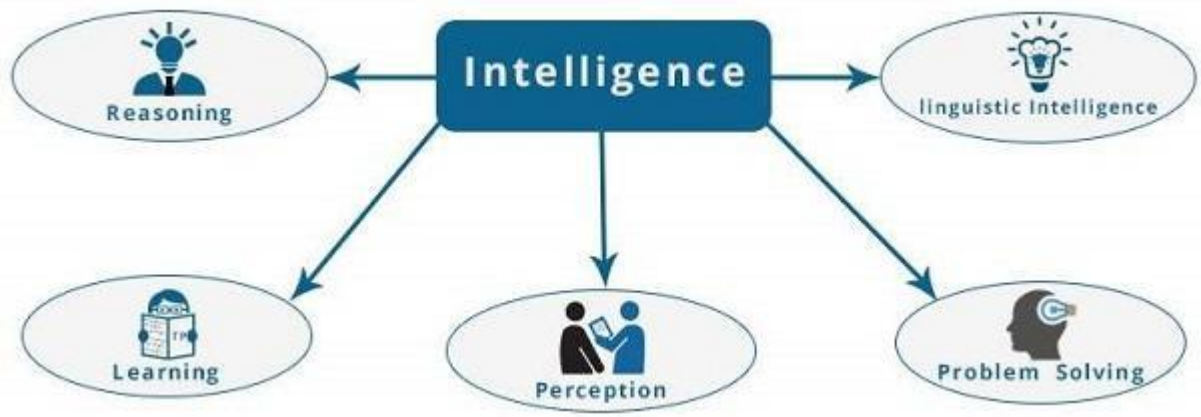
Intelligence	Description	Example
Linguistic intelligence	The ability to speak, recognize, and use mechanisms of phonology (speech sounds), syntax (grammar), and semantics (meaning).	Narrators, Orators
Musical intelligence	The ability to create, communicate with, and understand meanings made of sound, understanding of pitch, rhythm.	Musicians, Singers, Composers
Logical-mathematical intelligence	The ability to use and understand relationships in the absence of action or objects. Understanding complex and abstract ideas.	Mathematicians, Scientists
Spatial intelligence	The ability to perceive visual or spatial information, change it, and re-create visual images without reference to the objects, construct 3D images, and to move and rotate them.	Map readers, Astronauts, Physicists
Bodily-Kinesthetic intelligence	The ability to use complete or part of the body to solve problems or fashion products, control over fine and coarse motor skills, and manipulate the objects.	Players, Dancers
Intrapersonal intelligence	The ability to distinguish among one's own feelings, intentions, and motivations.	Gautam Buddhha
Interpersonal intelligence	The ability to recognize and make distinctions among other people's feelings, beliefs, and intentions.	Mass Communicators, Interviewers

You can say a machine or a system is **artificially intelligent** when it is equipped with at least one and at most all intelligences in it.

What is Intelligence Composed of?

Intelligence is intangible. It is composed of –

- Reasoning
- Learning
- Problem Solving
- Perception
- Linguistic Intelligence



Let us go through all the components briefly –

- **Reasoning** – It is the set of processes that enables us to provide basis for judgement, making decisions, and prediction. There are broadly two types –

Inductive Reasoning	**Deductive Reasoning**
It conducts specific observations to make broad general statements.	It starts with a general statement and examines the possibilities to reach a specific, logical conclusion.
Even if all of the premises are true in a statement, inductive reasoning allows for the conclusion to be false.	If something is true of a class of things in general, it is also true for all members of that class.
Example – "Nita is a teacher. Nita is studious. Therefore, All teachers are studious."	Example – "All women of age above 60 years are grandmothers. Shalini is 65 years old. Therefore, Shalini is a grandmother."

- **Learning** – It is the activity of gaining knowledge or skill by studying, practising, being taught, or experiencing something. Learning enhances the awareness of the subjects of the study.
  The ability of learning is possessed by humans, some animals, and AI-enabled systems. Learning is categorized as –

    - **Auditory Learning** – It is learning by listening and hearing. For example, students listening to recorded audio lectures.
    - **Episodic Learning** – To learn by remembering sequences of events that one has witnessed or experienced. This is linear and orderly.
    - **Motor Learning** – It is learning by precise movement of muscles. For example, picking objects, Writing, etc.
    - **Observational Learning** – To learn by watching and imitating others. For example, a child tries to learn by mimicking her parents.
    - **Perceptual Learning** – It is learning to recognize stimuli that one has seen before. For example, identifying and classifying objects and situations.
    - **Relational Learning** – It involves learning to differentiate among various stimuli on the basis of relational properties, rather than absolute properties. For Example, Adding 'little less' salt at the time of cooking potatoes that came up salty last time, when cooked with adding say a tablespoon of salt.
    - **Spatial Learning** – It is learning through visual stimuli such as images, colors, maps, etc. For Example, A person can create a roadmap in mind before actually following the road.
    - **Stimulus-Response Learning** – It is learning to perform a particular behavior when a certain stimulus is present. For example, a dog raises its ear on hearing a doorbell.
- **Problem Solving** – It is the process in which one perceives and tries to arrive at a desired solution from a present situation by taking some path, which is blocked by known or unknown hurdles.
  Problem solving also includes **decision making**, which is the process of selecting the best suitable alternative out of multiple alternatives to reach the desired goal are available.
- **Perception** – It is the process of acquiring, interpreting, selecting, and organizing sensory information.
  Perception presumes **sensing**. In humans, perception is aided by sensory organs. In the domain of AI, the perception mechanism puts the data acquired by the sensors together in a meaningful manner.
- **Linguistic Intelligence** – It is one's ability to use, comprehend, speak, and write the verbal and written language. It is important in interpersonal communication.

Difference between Human and Machine Intelligence

- Humans perceive by patterns whereas the machines perceive by a set of rules and data.
- Humans store and recall information by patterns, machines do it by searching algorithms. For example, the number 40404040 is easy to remember, store, and recall as its pattern is simple.
- Humans can figure out the complete object even if some part of it is missing or distorted; whereas the machines cannot do it correctly.

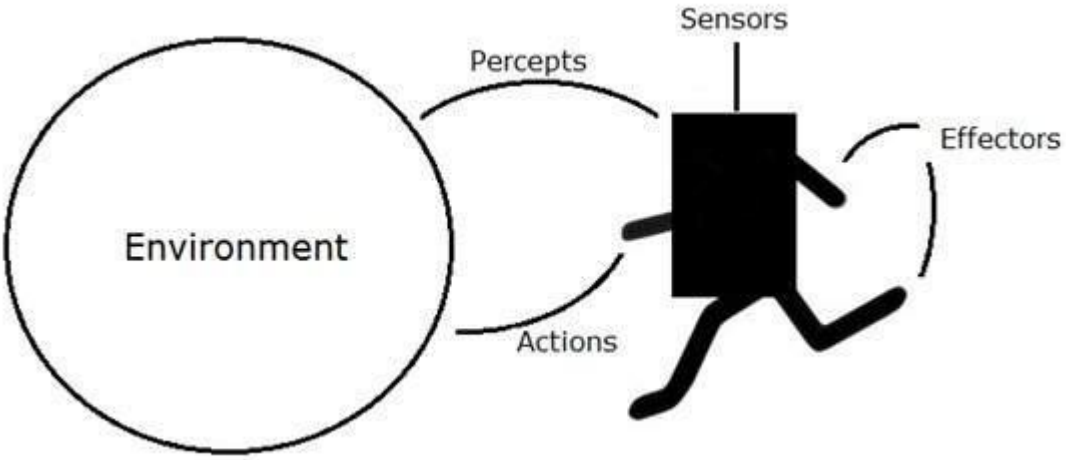
An AI system is composed of an agent and its environment. The agents act in their environment. The environment may contain other agents.

What are Agent and Environment?

An **agent** is anything that can perceive its environment through **sensors** and acts upon that environment through **effectors.**

- A **human agent** has sensory organs such as eyes, ears, nose, tongue and skin parallel to the sensors, and other organs such as hands, legs, mouth, for effectors.

- A **robotic agent** replaces cameras and infrared range finders for the sensors, and various motors and actuators for effectors.
- A **software agent** has encoded bit strings as its programs and actions.



Agent Terminology

- **Performance Measure of Agent** – It is the criteria, which determines how successful an agent is.
- **Behavior of Agent** – It is the action that agent performs after any given sequence of percepts.
- **Percept** – It is agent's perceptual inputs at a given instance.
- **Percept Sequence** – It is the history of all that an agent has perceived till date.
- **Agent Function** – It is a map from the precept sequence to an action.

Rationality

Rationality is nothing but the status of being reasonable, sensible, and having a good sense of judgment.

Rationality is concerned with expected actions and results depending upon what the agent has perceived. Performing actions with the aim of obtaining useful information is an important part of rationality.

What is an Ideal Rational Agent?

An ideal rational agent is the one, which is capable of doing expected actions to maximize its performance measure, on the basis of –

- Its percept sequence
- Its built-in knowledge base

Rationality of an agent depends on the following –

- The **performance measures**, which determine the degree of success.
- Agent's **Percept Sequence** till now.
- The agent's **prior knowledge about the environment**.
- The **actions** that the agent can carry out.

A rational agent always performs the right action, where the right action means the action that causes the agent to be most successful in the given percept sequence. The problem the agent solves is characterized by Performance Measure, Environment, Actuators, and Sensors (PEAS).

The Structure of Intelligent Agents

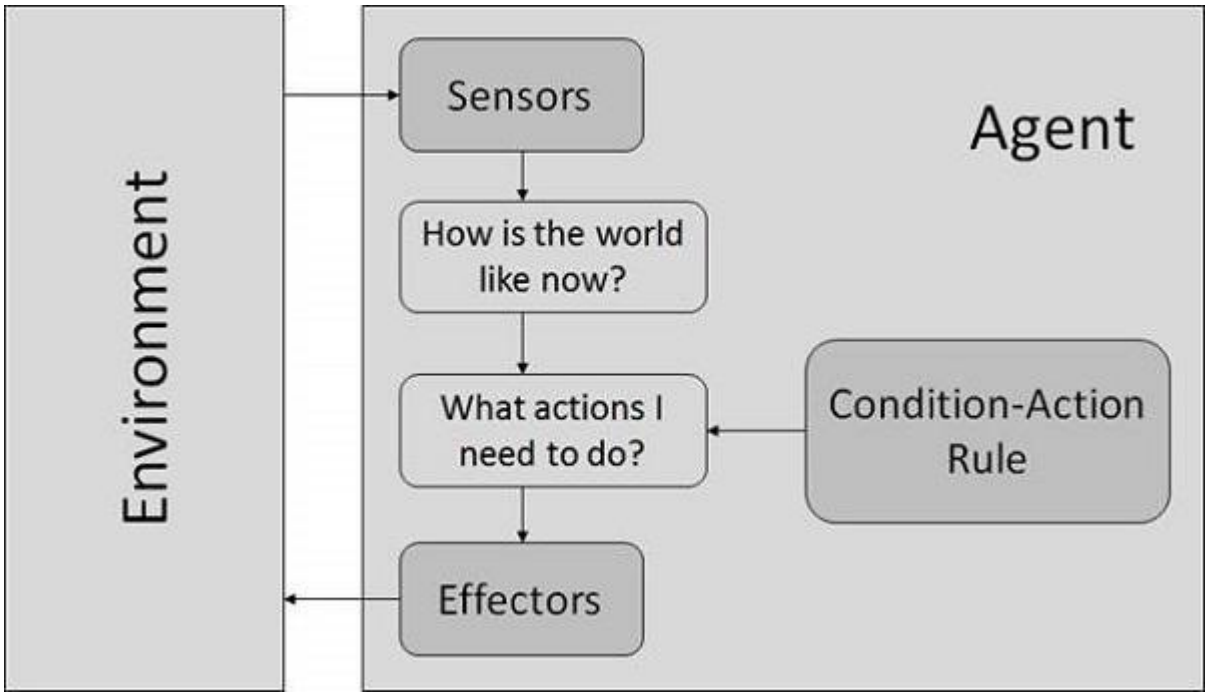
Agent's structure can be viewed as –

- Agent = Architecture + Agent Program
- Architecture = the machinery that an agent executes on.
- Agent Program = an implementation of an agent function.

Simple Reflex Agents

- They choose actions only based on the current percept.
- They are rational only if a correct decision is made only on the basis of current precept.
- Their environment is completely observable.

Condition-Action Rule – It is a rule that maps a state (condition) to an action.



Model Based Reflex Agents

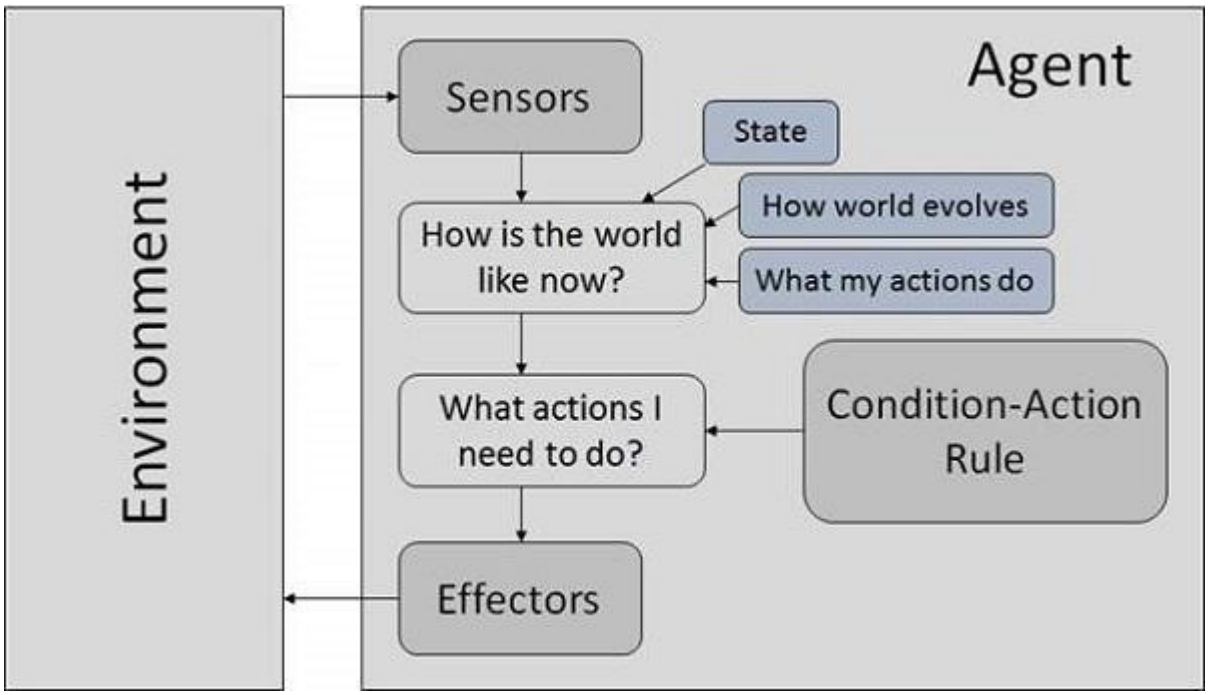
They use a model of the world to choose their actions. They maintain an internal state.

Model – knowledge about "how the things happen in the world".

Internal State – It is a representation of unobserved aspects of current state depending on percept history.

Updating the state requires the information about –

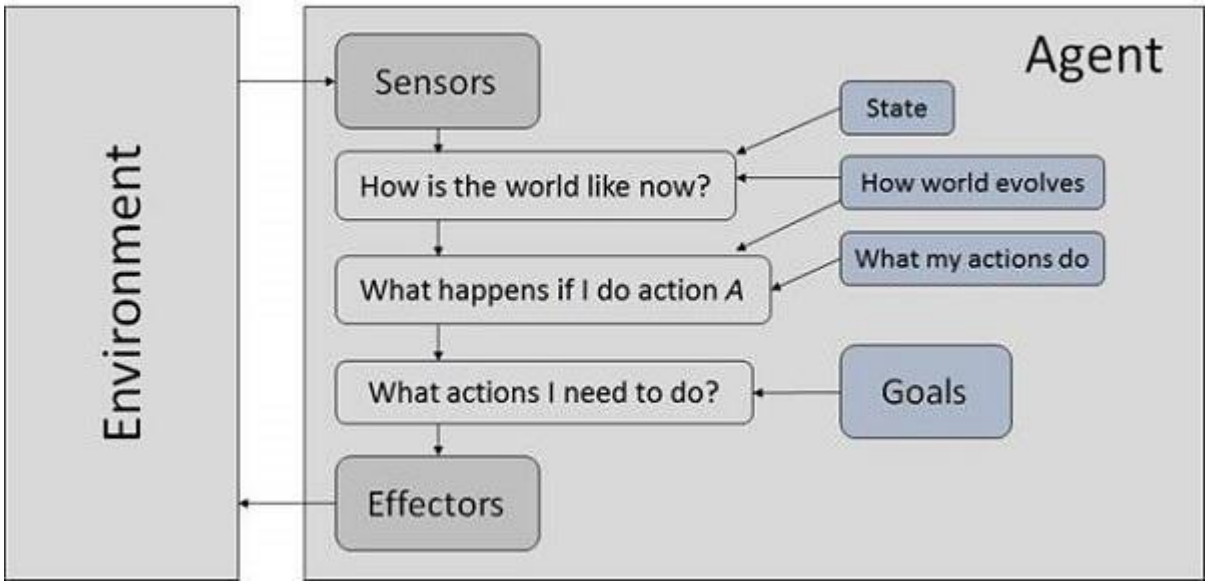
- How the world evolves.
- How the agent's actions affect the world.



Goal Based Agents

They choose their actions in order to achieve goals. Goal-based approach is more flexible than reflex agent since the knowledge supporting a decision is explicitly modeled, thereby allowing for modifications.

Goal – It is the description of desirable situations.



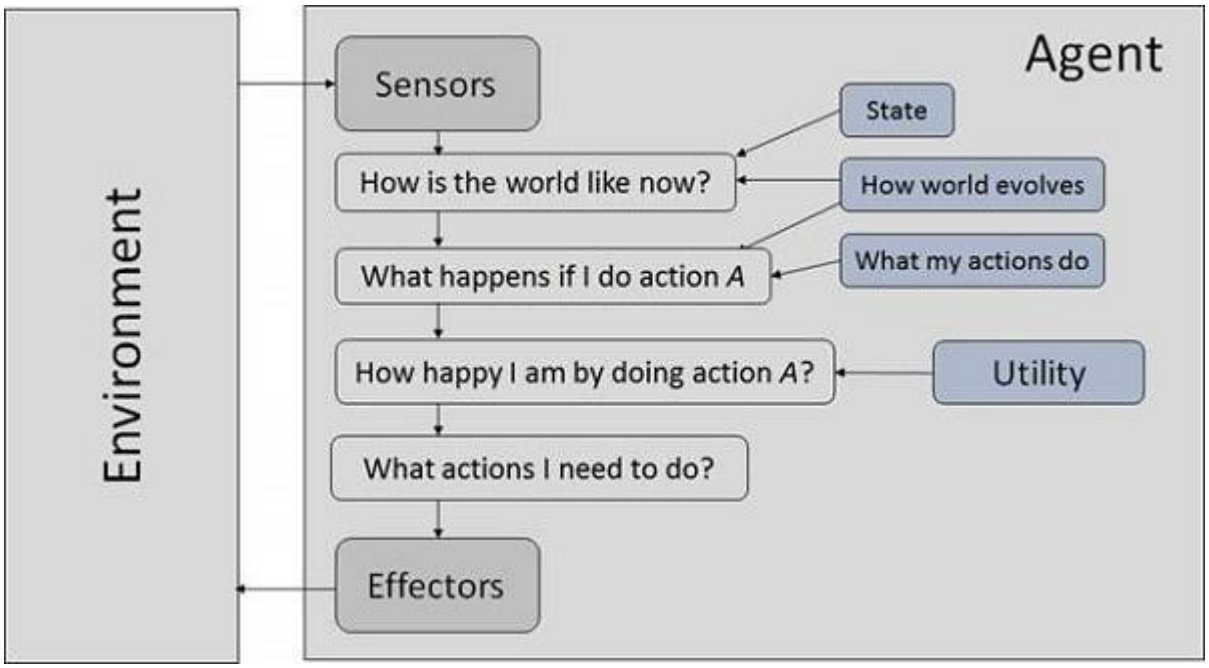
Utility Based Agents

They choose actions based on a preference (utility) for each state.

Goals are inadequate when –

- There are conflicting goals, out of which only few can be achieved.

- Goals have some uncertainty of being achieved and you need to weigh the likelihood of success against the importance of a goal.



The Nature of Environments

Some programs operate in the entirely **artificial environment** confined to keyboard input, database, computer file systems and character output on a screen.

In contrast, some software agents (software robots or softbots) exist in rich, unlimited softbots domains. The simulator has a **very detailed, complex environment**. The software agent needs to choose from a long array of actions in real time. A softbot designed to scan the online preferences of the customer and show interesting items to the customer works in the **real** as well as an **artificial** environment.

The most famous **artificial environment** is the **Turing Test environment**, in which one real and other artificial agents are tested on equal ground. This is a very challenging environment as it is highly difficult for a software agent to perform as well as a human.

Turing Test

The success of an intelligent behavior of a system can be measured with the Turing Test.

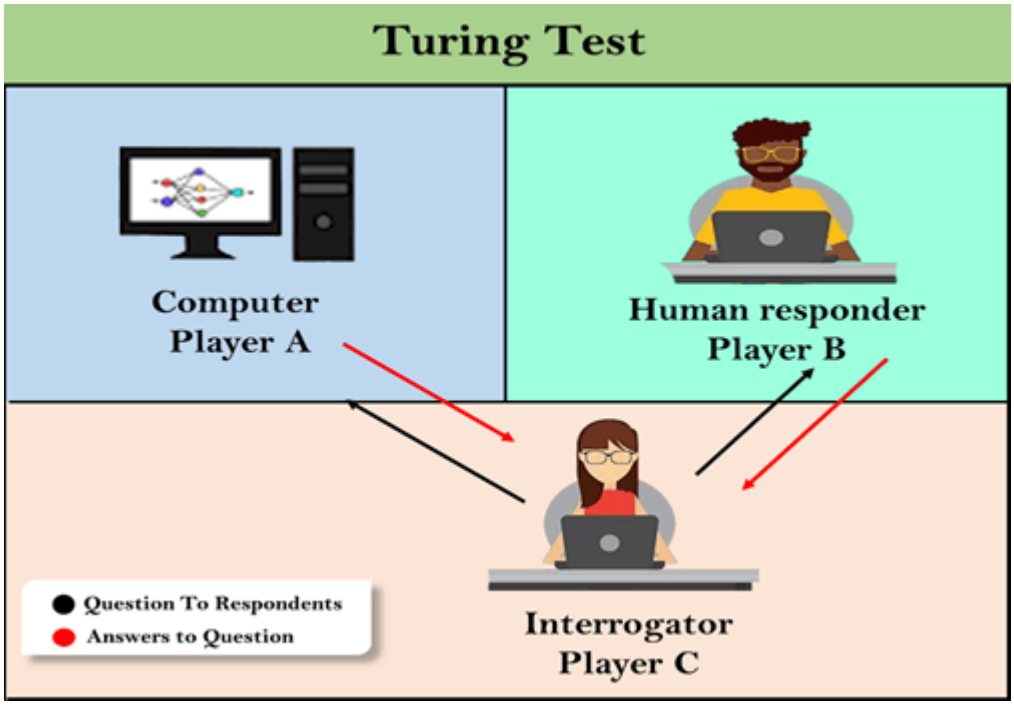
Two persons and a machine to be evaluated participate in the test. Out of the two persons, one plays the role of the tester. Each of them sits in different rooms. The tester is unaware of who is a machine and who is a human. He interrogates the questions by typing and sending them to both intelligences, to which he receives typed responses.

This test aims at fooling the tester. If the tester fails to determine the machine's response from the human response, then the machine is said to be intelligent.

Turing Test in AI

In 1950, Alan Turing introduced a test to check whether a machine can think like a human or not, this test is known as the Turing Test. In this test, Turing proposed that the computer can be said to be intelligent if it can mimic human response under specific conditions.

The Turing Test was introduced by Turing in his 1950 paper, "Computing Machinery and Intelligence," which considered the question, "Can machines think?"



The Turing test is based on a party game "Imitation game," with some modifications. This game involves three players in which one player is Computer, another player is human responder, and the third player is a human Interrogator, who is isolated from other two players and his job is to find which player is the machine among two of them.

Consider, Player A is a computer, Player B is human, and Player C is an interrogator. Interrogator is aware that one of them is a machine, but he needs to identify this on the basis of questions and their responses.

The conversation between all players is via keyboard and screen so the result would not depend on the machine's ability to convert words as speech.

The test result does not depend on each correct answer, but only how closely its responses are like a human answer. The computer is permitted to do everything possible to force a wrong identification by the interrogator.

The questions and answers can be like:

Interrogator: Are you a computer?

PlayerA (Computer): No

Interrogator: Multiply two large numbers such as (256896489*456725896)

Player A: Long pause and give the wrong answer.

In this game, if an interrogator would not be able to identify which is a machine and which is human, then the computer passes the test successfully, and the machine is said to be intelligent and can think like a human.

Properties of Environment

The environment has multifold properties –

- **Discrete / Continuous** – If there are a limited number of distinct, clearly defined, states of the environment, the environment is discrete (For example, chess); otherwise it is continuous (For example, driving).
- **Observable / Partially Observable** – If it is possible to determine the complete state of the environment at each time point from the percepts it is observable; otherwise it is only partially observable.
- **Static / Dynamic** – If the environment does not change while an agent is acting, then it is static; otherwise it is dynamic.
- **Single agent / Multiple agents** – The environment may contain other agents which may be of the same or different kind as that of the agent.
- **Accessible / Inaccessible** – If the agent's sensory apparatus can have access to the complete state of the environment, then the environment is accessible to that agent.
- **Deterministic / Non-deterministic** – If the next state of the environment is completely determined by the current state and the actions of the agent, then the environment is deterministic; otherwise it is non-deterministic.
- **Episodic / Non-episodic** – In an episodic environment, each episode consists of the agent perceiving and then acting. The quality of its action depends just on the episode itself. Subsequent episodes do not depend on the actions in the previous episodes. Episodic environments are much simpler because the agent does not need to think ahead.

Search Algorithms in Artificial Intelligence

Search algorithms are one of the most important areas of Artificial Intelligence. This topic will explain all about the search algorithms in AI.

Problem-solving agents:

In Artificial Intelligence, Search techniques are universal problem-solving methods. **Rational agents** or **Problem-solving agents** in AI mostly used these search strategies or algorithms to solve a specific problem and provide the best result. Problem-solving agents are the goal-based agents and use atomic representation. In this topic, we will learn various problem-solving search algorithms.

Search Algorithm Terminologies:

- **Search:** Searching Is a step by step procedure to solve a search-problem in a given search space. A search problem can have three main factors:

    a. **Search Space:** Search space represents a set of possible solutions, which a system may have.

    a. **Start State:** It is a state from where agent begins **the search**.

    b. **Goal test:** It is a function which observe the current state and returns whether the goal state is achieved or not.

Search tree: A tree representation of search problem is called Search tree. The root of the search tree is the root node which is corresponding to the initial state.

Actions: It gives the description of all the available actions to the agent.

Transition model: A description of what each action do, can be represented as a transition model.

Path Cost: It is a function which assigns a numeric cost to each path.

Solution: It is an action sequence which leads from the start node to the goal node.

Optimal Solution: If a solution has the lowest cost among all solutions.

Properties of Search Algorithms:

Following are the four essential properties of search algorithms to compare the efficiency of these algorithms:

Completeness: A search algorithm is said to be complete if it guarantees to return a solution if at least any solution exists for any random input.

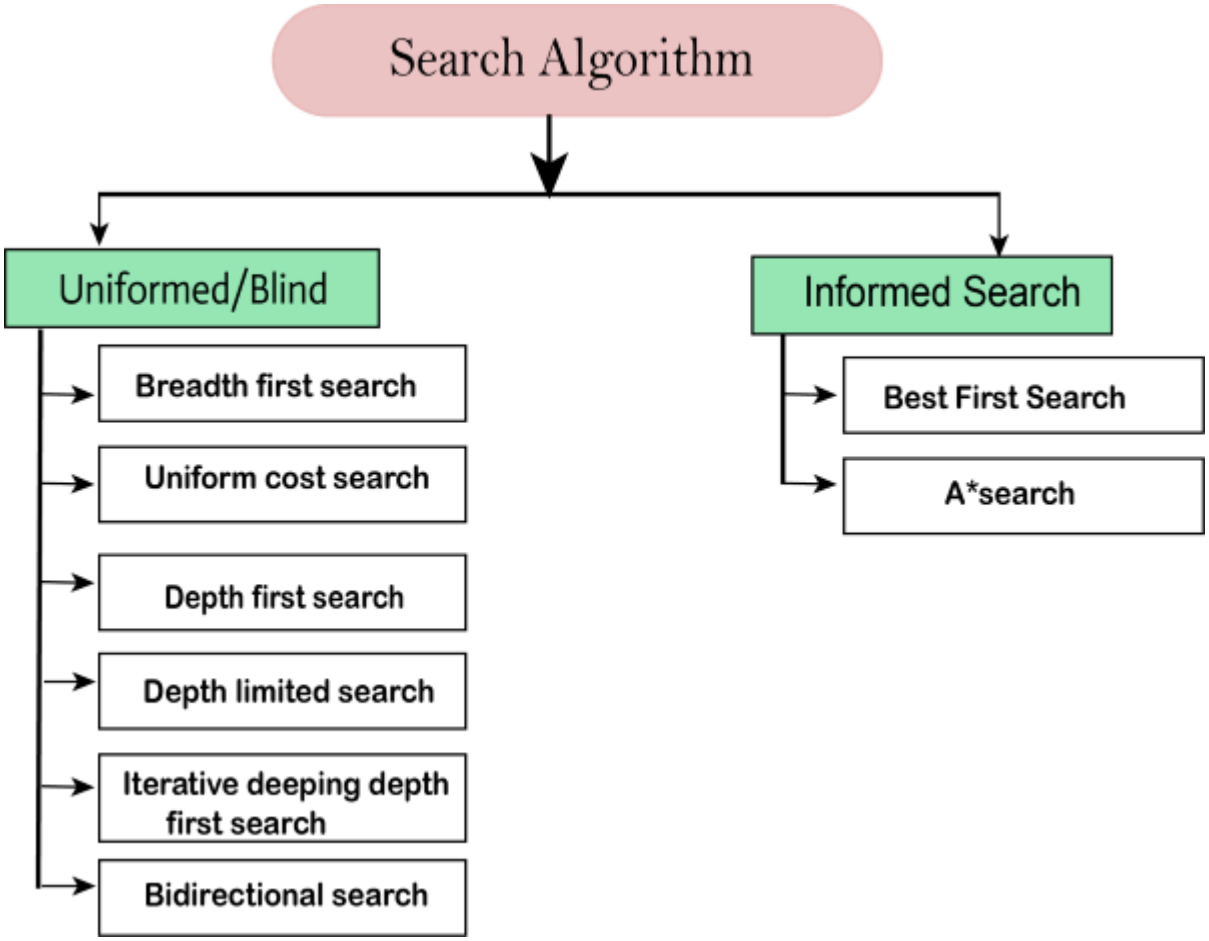
Optimality: If a solution found for an algorithm is guaranteed to be the best solution (lowest path cost) among all other solutions, then such a solution for is said to be an optimal solution.

Time Complexity: Time complexity is a measure of time for an algorithm to complete its task.

Space Complexity: It is the maximum storage space required at any point during the search, as the complexity of the problem.

Types of search algorithms

Based on the search problems we can classify the search algorithms into uninformed (Blind search) search and informed search (Heuristic search) algorithms.



Uninformed/Blind Search:

The uninformed search does not contain any domain knowledge such as closeness, the location of the goal. It operates in a brute-force way as it only includes information about how to traverse the tree and how to identify leaf and goal nodes. Uninformed search applies a way in which a search tree is searched without any information about the search space like initial state operators and test for the goal, so it is also called blind search.It examines each node of the tree until it achieves the goal node.

It can be divided into five main types:

- Breadth-first search
- Uniform cost search
- Depth-first search
- Iterative deepening depth-first search
- Bidirectional Search

Informed Search

Informed search algorithms use domain knowledge. In an informed search, problem information is available which can guide the search. Informed search strategies can find a solution more efficiently than an uninformed search strategy. Informed search is also called a Heuristic search.

A heuristic is a way which might not always be guaranteed for best solutions but guaranteed to find a good solution in reasonable time.

Informed search can solve many complex problems which could not be solved in another way.

An example of informed search algorithms is a traveling salesman problem.

1. Greedy Search
2. A* Search

Uninformed Search Algorithms

Uninformed search is a class of general-purpose search algorithms which operates in brute force-way. Uninformed search algorithms do not have additional information about state or search space other than how to traverse the tree, so it is also called blind search.

Following are the various types of uninformed search algorithms:

1. **Breadth-first Search**
2. **Depth-first Search**
3. **Depth-limited Search**
4. **Iterative deepening depth-first search**
5. **Uniform cost search**
6. **Bidirectional Search**

1. Breadth-first Search:

- Breadth-first search is the most common search strategy for traversing a tree or graph. This algorithm searches breadthwise in a tree or graph, so it is called breadth-first search.
- The BFS algorithm starts searching from the root node of the tree and expands all successor nodes at the current level before moving to nodes of the next level.
- The breadth-first search algorithm is an example of a general-graph search algorithm.
- Breadth-first search implemented using FIFO queue data structure.

Advantages:

- BFS will provide a solution if any solution exists.
- If there are more than one solutions for a given problem, then BFS will provide the minimal solution which requires the least number of steps.

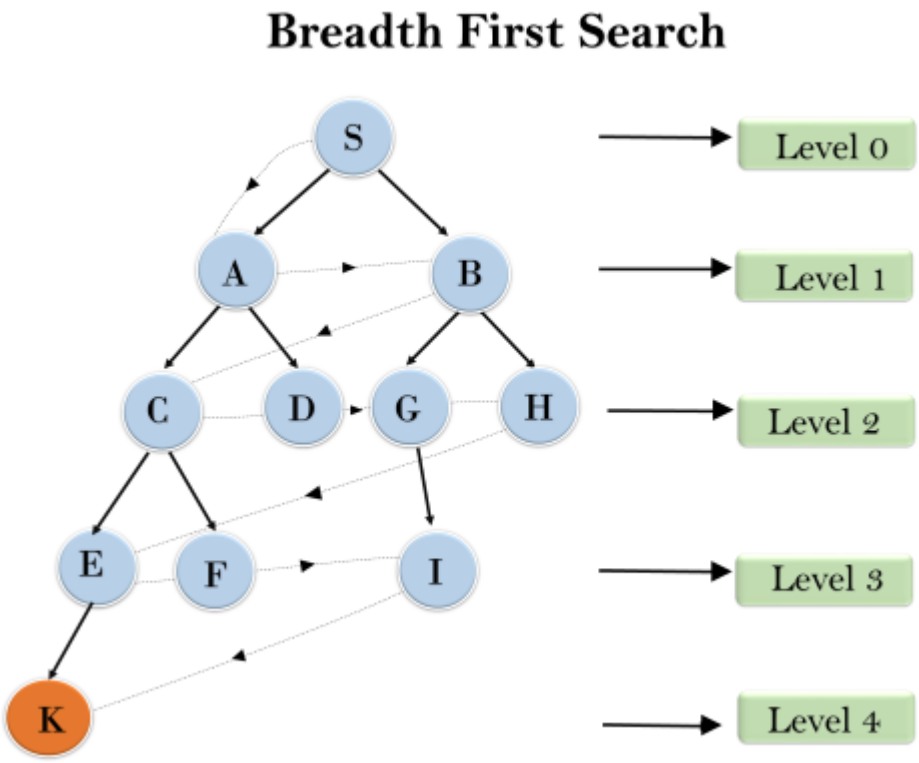
Disadvantages:

- It requires lots of memory since each level of the tree must be saved into memory to expand the next level.
- BFS needs lots of time if the solution is far away from the root node.

Example:

In the below tree structure, we have shown the traversing of the tree using BFS algorithm from the root node S to goal node K. BFS search algorithm traverse in layers, so it will follow the path which is shown by the dotted arrow, and the traversed path will be:

S---> A--->B---->C--->D---->G--->H--->E---->F---->I---->K



Time Complexity: Time Complexity of BFS algorithm can be obtained by the number of nodes traversed in BFS until the shallowest Node. Where the d= depth of shallowest solution and b is a node at every state.

$T(b) = 1+b^2+b^3+.....+ b^d = O(b^d)$

Space Complexity: Space complexity of BFS algorithm is given by the Memory size of frontier which is $O(b^d)$.

Completeness: BFS is complete, which means if the shallowest goal node is at some finite depth, then BFS will find a solution.

Optimality: BFS is optimal if path cost is a non-decreasing function of the depth of the node.

2. Depth-first Search

- Depth-first search isa recursive algorithm for traversing a tree or graph data structure.
- It is called the depth-first search because it starts from the root node and follows each path to its greatest depth node before moving to the next path.
- DFS uses a stack data structure for its implementation.
- The process of the DFS algorithm is similar to the BFS algorithm.

Note: Backtracking is an algorithm technique for finding all possible solutions using recursion.

Advantage:

- DFS requires very less memory as it only needs to store a stack of the nodes on the path from root node to the current node.
- It takes less time to reach the goal node than the BFS algorithm (if it traverses in the right path).

Disadvantage:

- There is the possibility that many states keep reoccurring, and there is no guarantee of finding the solution.

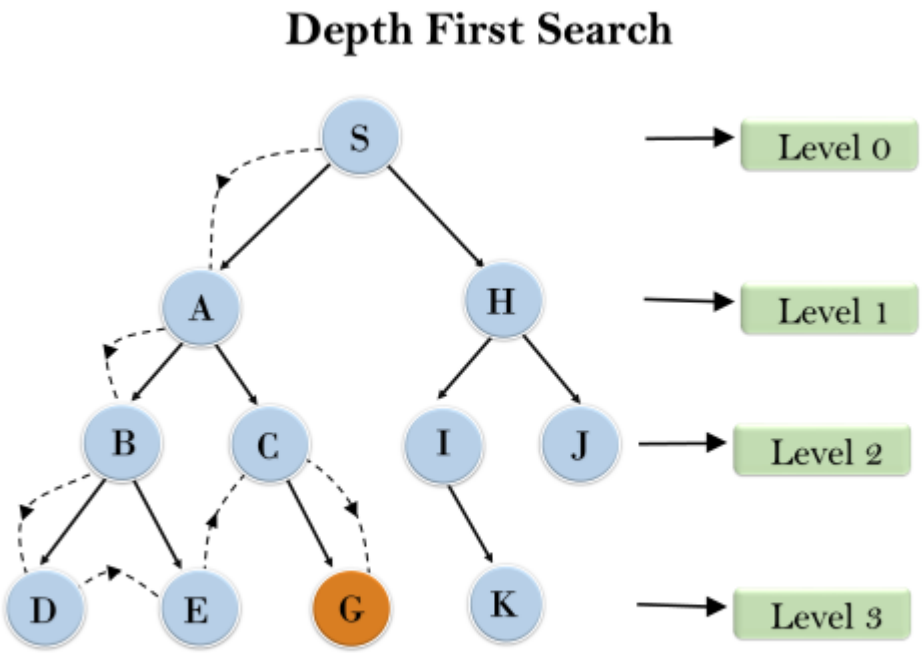
- The DFS algorithm goes for deep down searching and sometimes it may go to the infinite loop.

Example:

In the below search tree, we have shown the flow of depth-first search, and it will follow the order as:

Root node--->Left node ----> right node.

It will start searching from root node S, and traverse A, then B, then D and E, after traversing E, it will backtrack the tree as E has no other successor and still the goal node is not found. After backtracking it will traverse node C and then G, and here it will terminate as it found the goal node.



Completeness: DFS search algorithm is complete within finite state space as it will expand every node within a limited search tree.

Time Complexity: Time complexity of DFS will be equivalent to the node traversed by the algorithm. It is given by:

$T(n)= 1+ n^2+ n^3 +.....+ n^m=O(n^m)$

Where, m= maximum depth of any node and this can be much larger than d (Shallowest solution depth)

Space Complexity: DFS algorithm needs to store only single path from the root node, hence space complexity of DFS is equivalent to the size of the fringe set, which is **O(bm)**.

Optimal: DFS search algorithm is non-optimal, as it may generate a large number of steps or high cost to reach to the goal node.

3. Depth-Limited Search Algorithm:

A depth-limited search algorithm is similar to depth-first search with a predetermined limit. Depth-limited search can solve the drawback of the infinite path in the Depth-first search. In this algorithm, the node at the depth limit will be treated as it has no successor nodes further.

Depth-limited search can be terminated with two Conditions of failure:

- Standard failure value: It indicates that the problem does not have any solution.
- Cutoff failure value: It defines no solution for the problem within a given depth limit.

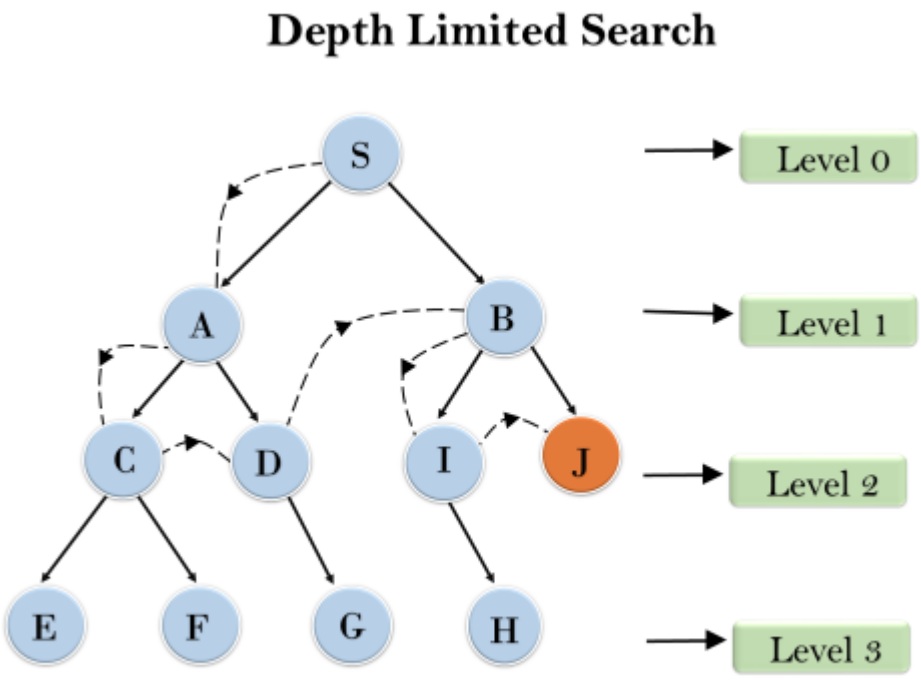
Advantages:

Depth-limited search is Memory efficient.

Disadvantages:

- Depth-limited search also has a disadvantage of incompleteness.
- It may not be optimal if the problem has more than one solution.

Example:



Completeness: DLS search algorithm is complete if the solution is above the depth-limit.

Time Complexity: Time complexity of DLS algorithm is **O(b^{ℓ})**.

Space Complexity: Space complexity of DLS algorithm is O**(b×ℓ)**.

4. Iterative deepening depth-first Search:

The iterative deepening algorithm is a combination of DFS and BFS algorithms. This search algorithm finds out the best depth limit and does it by gradually increasing the limit until a goal is found.

This algorithm performs depth-first search up to a certain "depth limit", and it keeps increasing the depth limit after each iteration until the goal node is found.

This Search algorithm combines the benefits of Breadth-first search's fast search and depth-first search's memory efficiency.

The iterative search algorithm is useful for uninformed search when the search space is large, and depth of the goal node is unknown.

Advantages:

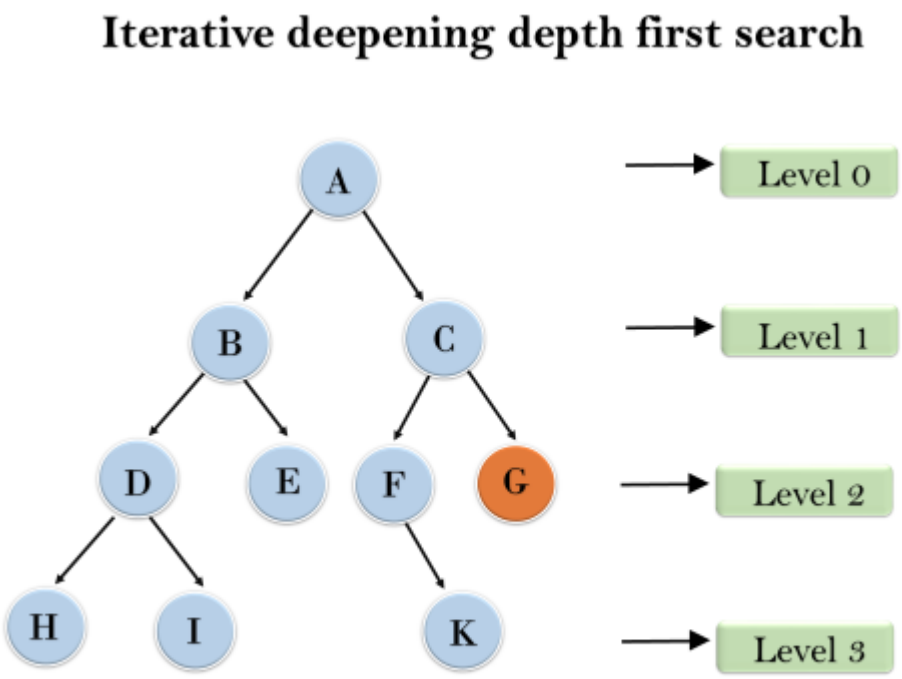
- It combines the benefits of BFS and DFS search algorithms in terms of fast search and memory efficiency.

Disadvantages:

- The main drawback of IDDFS is that it repeats all the work of the previous phase.

Example:

Following tree structure shows the iterative deepening depth-first search. The IDDFS algorithm performs various iterations until it does not find the goal node. The iteration performed by the algorithm is given as:



1'st Iteration-----> A
2'nd Iteration----> A, B, C
3'rd Iteration------>A, B, D, E, C, F, G
4'th Iteration------>A, B, D, H, I, E, C, F, K, G
In the fourth iteration, the algorithm will find the goal node.

Completeness:

This algorithm is complete if the branching factor is finite.

Time Complexity:

Let's suppose b is the branching factor and depth is d then the worst-case time complexity is **$O(b^d)$**.

Space Complexity:

The space complexity of IDDFS will be **O(bd)**.

Optimal:

The IDDFS algorithm is optimal if path cost is a non- decreasing function of the depth of the node.

Informed Search Algorithms

So far we have talked about the uninformed search algorithms which looked through search space for all possible solutions of the problem without having any additional knowledge about search space. But an informed search algorithm contains an array of knowledge such as how far we are from the goal, path cost, how to reach the goal node, etc. This knowledge helps agents to explore less of the search space and find the goal node more efficiently.

The informed search algorithm is more useful for large search spaces. Informed search algorithms use the idea of heuristic, so it is also called Heuristic search.

Heuristics function: Heuristic is a function which is used in Informed Search, and it finds the most promising path. It takes the current state of the agent as its input and produces the estimation of how close the agent is from the goal. The heuristic method, however, might not always give the best solution, but it guaranteed to find a good solution in reasonable time. Heuristic function estimates how close a state is to the goal. It is represented by h(n), and it calculates the cost of an optimal path between the pair of states. The value of the heuristic function is always positive.

Admissibility of the heuristic function is given as:

$h(n) <= h^*(n)$

Here h(n) is heuristic cost, and h*(n) is the estimated cost. Hence heuristic cost should be less than or equal to the estimated cost.

Pure Heuristic Search:

Pure heuristic search is the simplest form of heuristic search algorithms. It expands nodes based on their heuristic value h(n). It maintains two lists, OPEN and CLOSED list. In the CLOSED list, it places those nodes which have already expanded and in the OPEN list, it places nodes which have yet not been expanded.

On each iteration, each node n with the lowest heuristic value is expanded and generates all its successors and n is placed to the closed list. The algorithm continues until a goal state is found.

In the informed search we will discuss two main algorithms which are given below:

- **Best First Search Algorithm(Greedy search)**
- **A* Search Algorithm**

1.) Best-first Search Algorithm (Greedy Search):

Greedy best-first search algorithm always selects the path which appears best at that moment. It is the combination of depth-first search and breadth-first search algorithms. It uses the heuristic function and search. Best-first search allows us to take the advantages of both algorithms. With the help of best-first search, at each step, we can choose the most promising node. In the best first search algorithm, we expand the node which is closest to the goal node and the closest cost is estimated by heuristic function, i.e.

f(n)= g(n).
Were, h(n)= estimated cost from node n to the goal.

The greedy best first algorithm is implemented by the priority queue.

Best first search algorithm:

- **Step 1:** Place the starting node into the OPEN list.
- **Step 2:** If the OPEN list is empty, Stop and return failure.
- **Step 3:** Remove the node n, from the OPEN list which has the lowest value of h(n), and places it in the CLOSED list.
- **Step 4:** Expand the node n, and generate the successors of node n.
- **Step 5:** Check each successor of node n, and find whether any node is a goal node or not. If any successor node is a goal node, then return success and terminate the search, else proceed to Step 6.
- **Step 6:** For each successor node, algorithm checks for evaluation function f(n), and then check if the node has been in either OPEN or CLOSED list. If the node has not been in both lists, then add it to the OPEN list.
- **Step 7:** Return to Step 2.

Advantages:

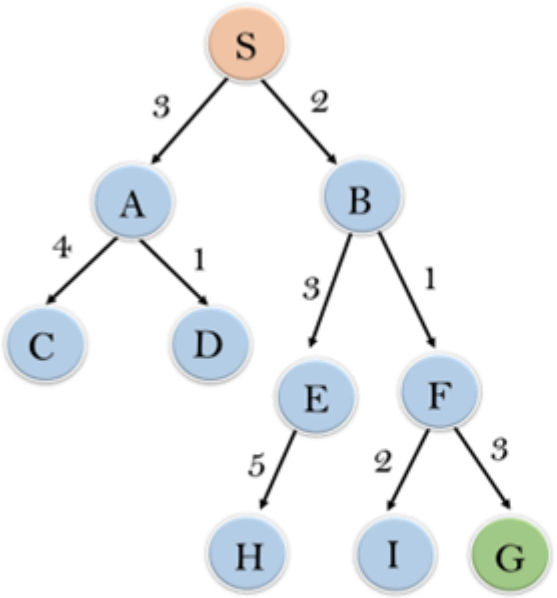
- Best first search can switch between BFS and DFS by gaining the advantages of both the algorithms.
- This algorithm is more efficient than BFS and DFS algorithms.

Disadvantages:

- It can behave as an unguided depth-first search in the worst case scenario.
- It can get stuck in a loop as DFS.
- This algorithm is not optimal.

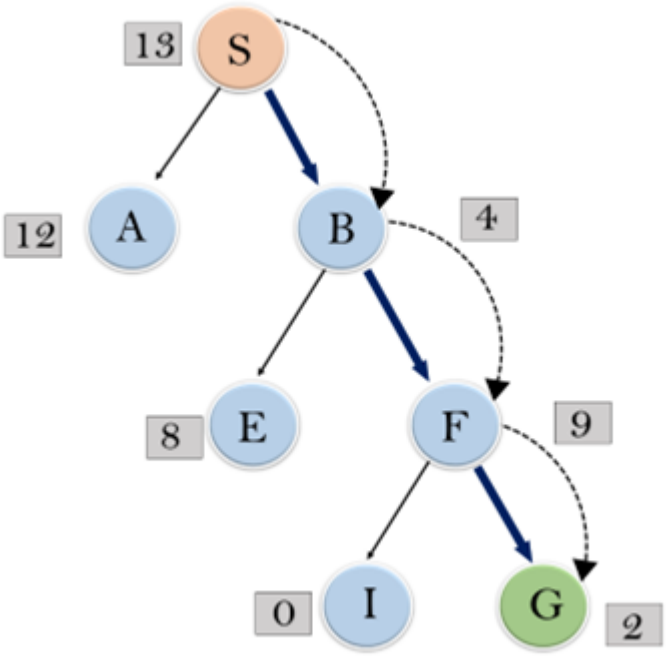
Example:

Consider the below search problem, and we will traverse it using greedy best-first search. At each iteration, each node is expanded using the evaluation function f(n)=h(n) , which is given in the below table.



node	H (n)
A	12
B	4
C	7
D	3
E	8
F	2
H	4
I	9
S	13
G	0

In this search example, we are using two lists which are **OPEN** and **CLOSED** Lists. Following are the iterations for traversing the above example.



Expand the nodes of S and put in the CLOSED list

Initialization: Open [A, B], Closed [S]

Iteration 1: Open [A], Closed [S, B]

Iteration 2: Open [E, F, A], Closed [S, B]
: Open [E, A], Closed [S, B, F]

Iteration 3: Open [I, G, E, A], Closed [S, B, F]
: Open [I, E, A], Closed [S, B, F, G]

Hence the final solution path will be: **S----> B----->F----> G**

Time Complexity: The worst case time complexity of Greedy best first search is $O(b^m)$.

Space Complexity: The worst case space complexity of Greedy best first search is $O(b^m)$. Where, m is the maximum depth of the search space.

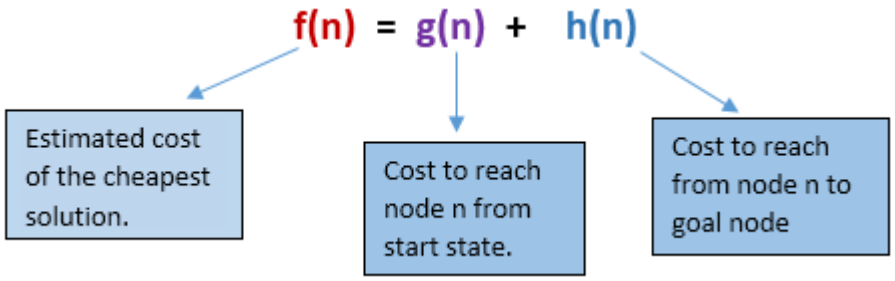
Complete: Greedy best-first search is also incomplete, even if the given state space is finite.

Optimal: Greedy best first search algorithm is not optimal.

2.) A* Search Algorithm:

A* search is the most commonly known form of best-first search. It uses the heuristic function h(n), and the cost to reach the node n from the start state g(n). It has combined features of UCS and greedy best-first search, by which it solves the problem efficiently. A* search algorithm finds the shortest path through the search space using the heuristic function. This search algorithm expands the search tree and provides optimal results faster. The A* The algorithm is similar to UCS except that it uses g(n)+h(n) instead of g(n).

In A* search algorithm, we use search heuristic as well as the cost to reach the node. Hence we can combine both costs as following, and this sum is called as a **fitness number**.


f(n) = g(n) + h(n)
Estimated cost of the cheapest solution.
Cost to reach node n from start state.
Cost to reach from node n to goal node

At each point in the search space, only those nodes are expanded which have the lowest value of f(n), and the algorithm terminates when the goal node is found.

Algorithm of A* search:

Step1: Place the starting node in the OPEN list.

Step 2: Check if the OPEN list is empty or not, if the list is empty then return failure and stops.

Step 3: Select the node from the OPEN list which has the smallest value of evaluation function (g+h), if node n is goal node then return success and stop, otherwise

Step 4: Expand node n and generate all of its successors, and put n into the closed list. For each successor n', check whether n' is already in the OPEN or CLOSED list, if not then compute the evaluation function for n' and place it into the Open list.

Step 5: Else if node n' is already in OPEN and CLOSED, then it should be attached to the back pointer which reflects the lowest g(n') value.

Step 6: Return to **Step 2**.

Advantages:

- A* search algorithm is the best algorithm than other search algorithms.
- A* The search algorithm is optimal and complete.
- This algorithm can solve very complex problems.

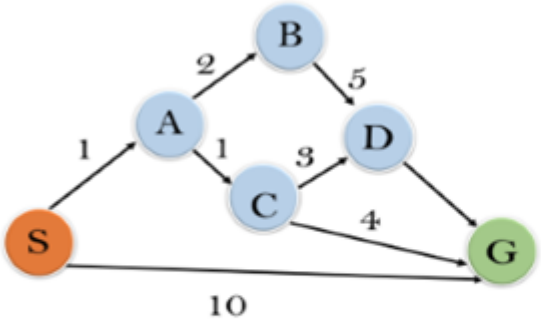
Disadvantages:

- It does not always produce the shortest path as it is mostly based on heuristics and approximation.
- A* The search algorithm has some complexity issues.
- The main drawback of A* is memory requirement as it keeps all generated nodes in the memory, so it is not practical for various large-scale problems.

Example:

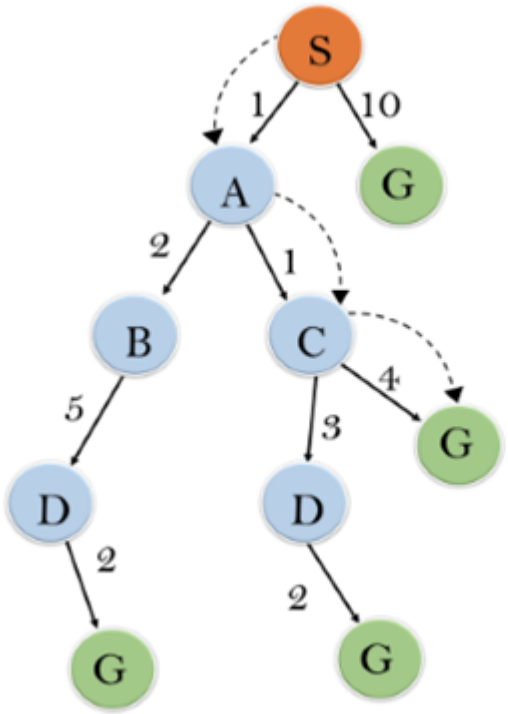
In this example, we will traverse the given graph using the A* algorithm. The heuristic value of all states is given in the below table so we will calculate the f(n) of each state using the formula f(n)= g(n) + h(n), where g(n) is the cost to reach any node from the start state.

Here we will use an OPEN and CLOSED list.



State	h(n)
S	5
A	3
B	4
C	2
D	6
G	0

Solution:



Initialization: {(S, 5)}

Iteration 1: {(S--> A, 4), (S-->G, 10)}

Iteration2: {(S--> A-->C, 4), (S--> A-->B, 7), (S-->G, 10)}

Iteration3: {(S--> A-->C--->G, 6), (S--> A-->C--->D, 11), (S--> A-->B, 7), (S-->G, 10)}

Iteration 4 will give the final result, as **S--->A--->C--->G** it provides the optimal path with cost 6.

Points to remember:

- A* algorithm returns the path which occurred first, and it does not search for all remaining paths.
- The efficiency of A* algorithm depends on the quality of heuristic.
- A* algorithm expands all nodes which satisfy the condition f(n)<="" li="">

Complete: A* algorithm is complete as long as:

- Branching factor is finite.
- Cost at every action is fixed.

Optimal: A* search algorithm is optimal if it follows below two conditions:

- **Admissible:** the first condition requires for optimality is that h(n) should be an admissible heuristic for A* tree search. An admissible heuristic is optimistic in nature.
- **Consistency:** Second required condition is consistency for only A* graph-search.

If the heuristic function is admissible, then A* tree search will always find the least cost path.

Time Complexity: The time complexity of A* The search algorithm depends on heuristic function, and the number of nodes expanded is exponential to the depth of solution d. So the time complexity is O(b^d), where b is the branching factor.

Space Complexity: The space complexity of A* search algorithm is **O(b^d)**

Hill Climbing Algorithm in Artificial Intelligence

- Hill climbing algorithm is a local search algorithm which continuously moves in the direction of increasing elevation/value to find the peak of the mountain or best solution to the problem. It terminates when it reaches a peak value where no neighbor has a higher value.
- Hill climbing algorithm is a technique which is used for optimizing mathematical problems. One of the widely discussed examples of Hill climbing algorithms is the Traveling-salesman Problem in which we need to minimize the distance traveled by the salesman.
- It is also called greedy local search as it only looks to its good immediate neighbor state and not beyond that.
- A node of hill climbing algorithm has two components which are state and value.
- Hill Climbing is mostly used when a good heuristic is available.
- In this algorithm, we don't need to maintain and handle the search tree or graph as it only keeps a single current state.

Features of Hill Climbing:

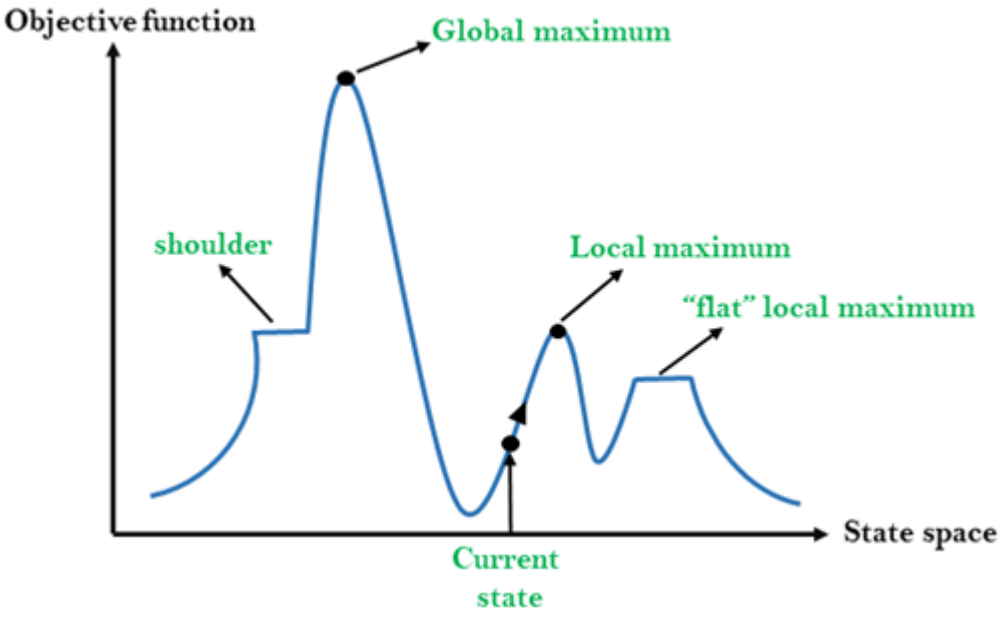
Following are some main features of Hill Climbing Algorithm:

- **Generate and Test variant:** Hill Climbing is the variant of Generate and Test method. The Generate and Test method produce feedback which helps to decide which direction to move in the search space.
- **Greedy approach:** Hill-climbing algorithm search moves in the direction which optimizes the cost.
- **No backtracking:** It does not backtrack the search space, as it does not remember the previous states.

State-space Diagram for Hill Climbing:

The state-space landscape is a graphical representation of the hill-climbing algorithm which is showing a graph between various states of algorithm and Objective function/Cost.

On the Y-axis we have taken the function which can be an objective function or cost function, and state-space on the x-axis. If the function on Y-axis is cost then, the goal of search is to find the global minimum and local minimum. If the function of the Y-axis is Objective function, then the goal of the search is to find the global maximum and local maximum.



Different regions in the state space landscape:

Local Maximum: Local maximum is a state which is better than its neighbor states, but there is also another state which is higher than it.

Global Maximum: Global maximum is the best possible state of state space landscape. It has the highest value of objective function.

Current state: It is a state in a landscape diagram where an agent is currently present.

Flat local maximum: It is a flat space in the landscape where all the neighbor states of current states have the same value.

Shoulder: It is a plateau region which has an uphill edge.

Types of Hill Climbing Algorithm:

- Simple hill Climbing:
- Steepest-Ascent hill-climbing:
- Stochastic hill Climbing:

1. Simple Hill Climbing:

Simple hill climbing is the simplest way to implement a hill climbing algorithm. **It only evaluates the neighbor node state at a time and selects the first one which optimizes current cost and sets it as a current state**. It only checks its one successor state, and if it finds better than the current state, then move else be in the same state. This algorithm has the following features:

- Less time consuming
- Less optimal solution and the solution is not guaranteed

Algorithm for Simple Hill Climbing:

- **Step 1:** Evaluate the initial state, if it is goal state then return success and Stop.
- **Step 2:** Loop Until a solution is found or there is no new operator left to apply.
- **Step 3:** Select and apply an operator to the current state.
- **Step 4:** Check new state:

    a. If it is a goal state, then return success and quit.
    a. Else if it is better than the current state then assign a new state as a current state.
    b. Else if not better than the current state, then return to step2.

- **Step 5:** Exit.

2. Steepest-Ascent hill climbing:

The steepest-Ascent algorithm is a variation of a simple hill climbing algorithm. This algorithm examines all the neighboring nodes of the current state and selects one neighbor node which is closest to the goal state. This algorithm consumes more time as it searches for multiple neighbors

Algorithm for Steepest-Ascent hill climbing:

- **Step 1:** Evaluate the initial state, if it is goal state then return success and stop, else make current state as initial state.
- **Step 2:** Loop until a solution is found or the current state does not change.

    a. Let SUCC be a state such that any successor of the current state will be better than it.
    a. For each operator that applies to the current state:

        a. Apply the new operator and generate a new state.
        a. Evaluate the new state.
        b. If it is a goal state, then return it and quit, else compare it to the SUCC.
        c. If it is better than SUCC, then set a new state as SUCC.
        d. If the SUCC is better than the current state, then set the current state to SUCC.

Step 5: Exit.

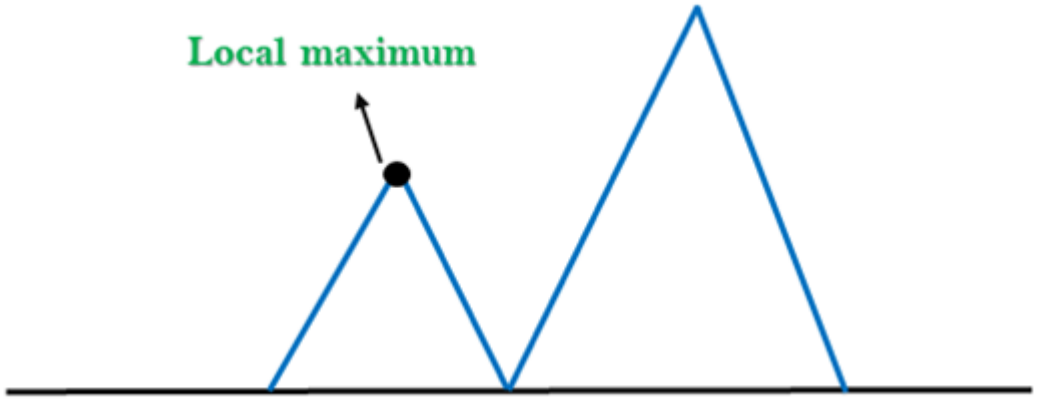
3. Stochastic hill climbing:

Stochastic hill climbing does not examine all its neighbors before moving. Rather, this search algorithm selects one neighbor node at random and decides whether to choose it as a current state or examine another state.

Problems in Hill Climbing Algorithm:

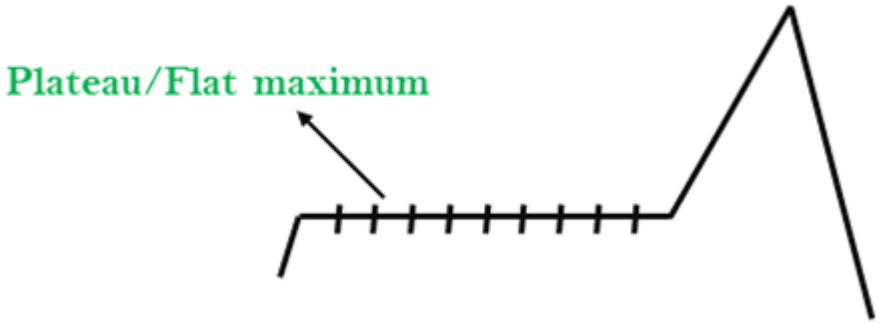
1. Local Maximum: A local maximum is a peak state in the landscape which is better than each of its neighboring states, but there is another state also present which is higher than the local maximum.

Solution: Backtracking technique can be a solution of the local maximum in state space landscape. Create a list of the promising path so that the algorithm can backtrack the search space and explore other paths as well.



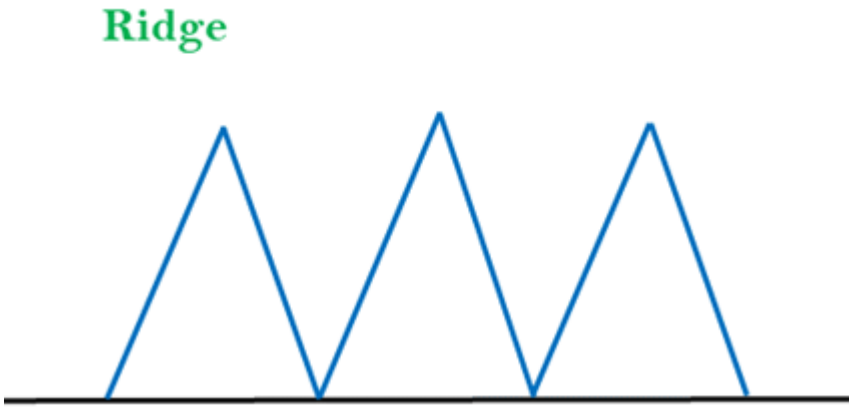
2. Plateau: A plateau is the flat area of the search space in which all the neighbor states of the current state contains the same value, because of this algorithm does not find any best direction to move. A hill-climbing search might be lost in the plateau area.

Solution: The solution for the plateau is to take big steps or very little steps while searching, to solve the problem. Randomly select a state which is far away from the current state so it is possible that the algorithm could find a non-plateau region.



3. Ridges: A ridge is a special form of the local maximum. It has an area which is higher than its surrounding areas, but itself has a slope, and cannot be reached in a single move.

Solution: With the use of bidirectional search, or by moving in different directions, we can improve this problem.



Simulated Annealing:

A hill-climbing algorithm which never makes a move towards a lower value is guaranteed to be incomplete because it can get stuck on a local maximum. And if the algorithm applies a random walk, by moving a successor, then it may be complete but not efficient. **Simulated Annealing** is an algorithm which yields both efficiency and completeness.

In mechanical term **Annealing** is a process of hardening a metal or glass to a high temperature then cooling gradually, so this allows the metal to reach a low-energy crystalline state. The same process is used in simulated annealing in which the algorithm picks a random move, instead of picking the best move. If the random move improves the state, then it follows the same path. Otherwise, the algorithm follows the path which has a probability of less than 1 or it moves downhill and chooses another path.

Means-Ends Analysis in Artificial Intelligence

- We have studied the strategies which can reason either in forward or backward, but a mixture of the two directions is appropriate for solving a complex and large problem. Such a mixed strategy makes it possible to first solve the major part of a problem and then go back and solve the small problems that arise during combining the big parts of the problem. Such a technique is called **Means-Ends Analysis**.
- Means-Ends Analysis is problem-solving techniques used in Artificial intelligence for limiting search in AI programs.
- It is a mixture of Backward and forward search techniques.
- The MEA technique was first introduced in 1961 by Allen Newell, and Herbert A. Simon in their problem-solving computer program, which was named as General Problem Solver (GPS).
- The MEA analysis process centered on the evaluation of the difference between the current state and goal state.

How means-ends analysis Works:

The means-ends analysis process can be applied recursively for a problem. It is a strategy to control search in problem-solving. Following are the main Steps which describe the working of MEA techniques for solving a problem.

a. First, evaluate the difference between Initial State and final State.
   a. Select the various operators which can be applied for each difference.
   b. Apply the operator at each difference, which reduces the difference between the current state and goal state.

Operator Subgoaling

In the MEA process, we detect the differences between the current state and goal state. Once these differences occur, then we can apply an operator to reduce the differences. But sometimes it is possible that an operator cannot be applied to the current state. So we create the subproblem of the current state, in which operator can be applied, such type of backward chaining in which operators are selected, and then sub goals are set up to establish the preconditions of the operator is called **Operator Subgoaling**.

Algorithm for Means-Ends Analysis:

Let's take Current state as CURRENT and Goal State as GOAL, then following are the steps for the MEA algorithm.

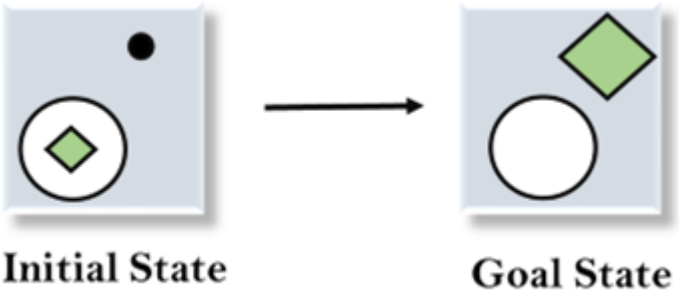
- **Step 1:** Compare CURRENT to GOAL, if there are no differences between both then return Success and Exit.
- **Step 2:** Else, select the most significant difference and reduce it by doing the following steps until the success or failure occurs.

a. Select a new operator O which is applicable for the current difference, and if there is no such operator, then signal failure.
   a. Attempt to apply operator O to CURRENT. Make a description of two states.
      i) O-Start, a state in which O?s preconditions are satisfied.
      ii) O-Result, the state that would result if O were applied In O-start.
   b. If
      (First-Part <------ MEA (CURRENT, O-START)
      And
      (LAST-Part <----- MEA (O-Result, GOAL), are successful, then signal Success and return the result of combining FIRST-PART, O, and LAST-PART.

The above-discussed algorithm is more suitable for a simple problem and not adequate for solving complex problems.

Example of Mean-Ends Analysis:

Let's take an example where we know the initial state and goal state as given below. In this problem, we need to get the goal state by finding differences between the initial state and goal state and applying operators.



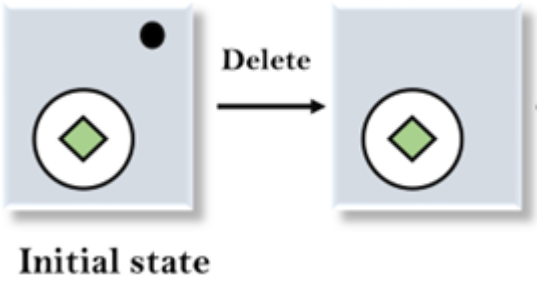
Solution:

To solve the above problem, we will first find the differences between initial states and goal states, and for each difference, we will generate a new state and will apply the operators. The operators we have for this problem are:

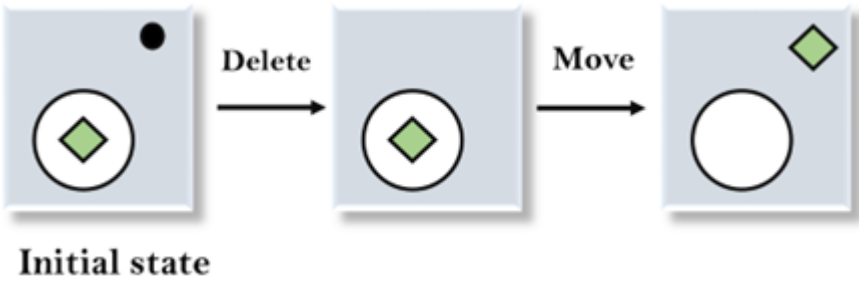
- **Move**
- **Delete**
- **Expand**

1. Evaluating the initial state: In the first step, we will evaluate the initial state and will compare the initial and Goal state to find the differences between both states.

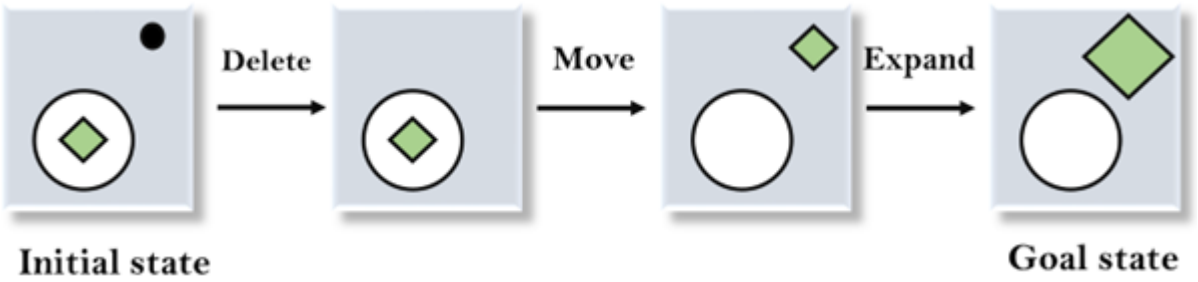
2. Applying Delete operator: As we can check the first difference is that in goal state there is no dot symbol which is present in the initial state, so, first we will apply the **Delete operator** to remove this dot.



3. Applying Move Operator: After applying the Delete operator, the new state occurs which we will again compare with goal state. After comparing these states, there is another difference that is the square is outside the circle, so, we will apply the **Move Operator**.



4. Applying Expand Operator: Now a new state is generated in the third step, and we will compare this state with the goal state. After comparing the states there is still one difference which is the size of the square, so, we will apply **Expand operator**, and finally, it will generate the goal state.



Adversarial Search

Adversarial search is a search, where we examine the problem which arises when we try to plan ahead of the world and other agents are planning against us.

- In previous topics, we have studied the search strategies which are only associated with a single agent that aims to find the solution which is often expressed in the form of a sequence of actions.
- But, there might be some situations where more than one agent is searching for the solution in the same search space, and this situation usually occurs in game playing.
- The environment with more than one agent is termed as **multi-agent environment**, in which each agent is an opponent of other agent and playing against each other. Each agent needs to consider the action of another agent and the effect of that action on their performance.
- So, **Searches in which two or more players with conflicting goals are trying to explore the same search space for the solution, are called adversarial searches, often known as Games**.
- Games are modeled as a Search problem and heuristic evaluation function, and these are the two main factors which help to model and solve games in AI.

Types of Games in AI:

	Deterministic	Chance Moves
Perfect information	Chess, Checkers, go, Othello	Backgammon, monopoly
Imperfect information	Battleships, blind, tic-tac-toe	Bridge, poker, scrabble, nuclear war

- **Perfect information:** A game with the perfect information is that in which agents can look into the complete board. Agents have all the information about the game, and they can see each other's moves also. Examples are Chess, Checkers, Go, etc.
- **Imperfect information:** If in a game agents do not have all information about the game and not aware with what's going on, such type of games are called the game with imperfect information, such as tic-tac-toe, Battleship, blind, Bridge, etc.
- **Deterministic games:** Deterministic games are those games which follow a strict pattern and set of rules for the games, and there is no randomness associated with them. Examples are chess, Checkers, Go, tic-tac-toe, etc.
- **Non-deterministic games:** Non-deterministic are those games which have various unpredictable events and has a factor of chance or luck. This factor of chance or luck is introduced by either dice or cards. These are random, and each action response is not fixed. Such games are also called stochastic games.
  Example: Backgammon, Monopoly, Poker, etc.

Note: In this topic, we will discuss deterministic games, fully observable environment, zero-sum, and where each agent acts alternatively.

Zero-Sum Game

- Zero-sum games are adversarial search which involves pure competition.
- In Zero-sum games each agent's gain or loss of utility is exactly balanced by the losses or gains of utility of another agent.

- One player of the game tries to maximize one single value, while another player tries to minimize it.
- Each move by one player in the game is called ply.
- Chess and tic-tac-toe are examples of a Zero-sum game.

Zero-sum game: Embedded thinking

The Zero-sum game involved embedded thinking in which one agent or player is trying to figure out:

- What to do.
- How to decide the move
- Needs to think about his opponent as well
- The opponent also thinks what to do

Each of the players is trying to find out the response of his opponent to their actions. This requires embedded thinking or backward reasoning to solve the game problems in AI.

Formalization of the problem:

A game can be defined as a type of search in AI which can be formalized of the following elements:

- **Initial state:** It specifies how the game is set up at the start.
- **Player(s):** It specifies which player has moved in the state space.
- **Action(s):** It returns the set of legal moves in state space.
- **Result(s, a):** It is the transition model, which specifies the result of moves in the state space.
- **Terminal-Test(s):** Terminal test is true if the game is over, else it is false at any case. The state where the game ends is called terminal states.
- **Utility(s, p):** A utility function gives the final numeric value for a game that ends in terminal states s for player p. It is also called the payoff function. For Chess, the outcomes are a win, loss, or draw and its payoff values are +1, 0, ½. And for tic-tac-toe, utility values are +1, -1, and 0.

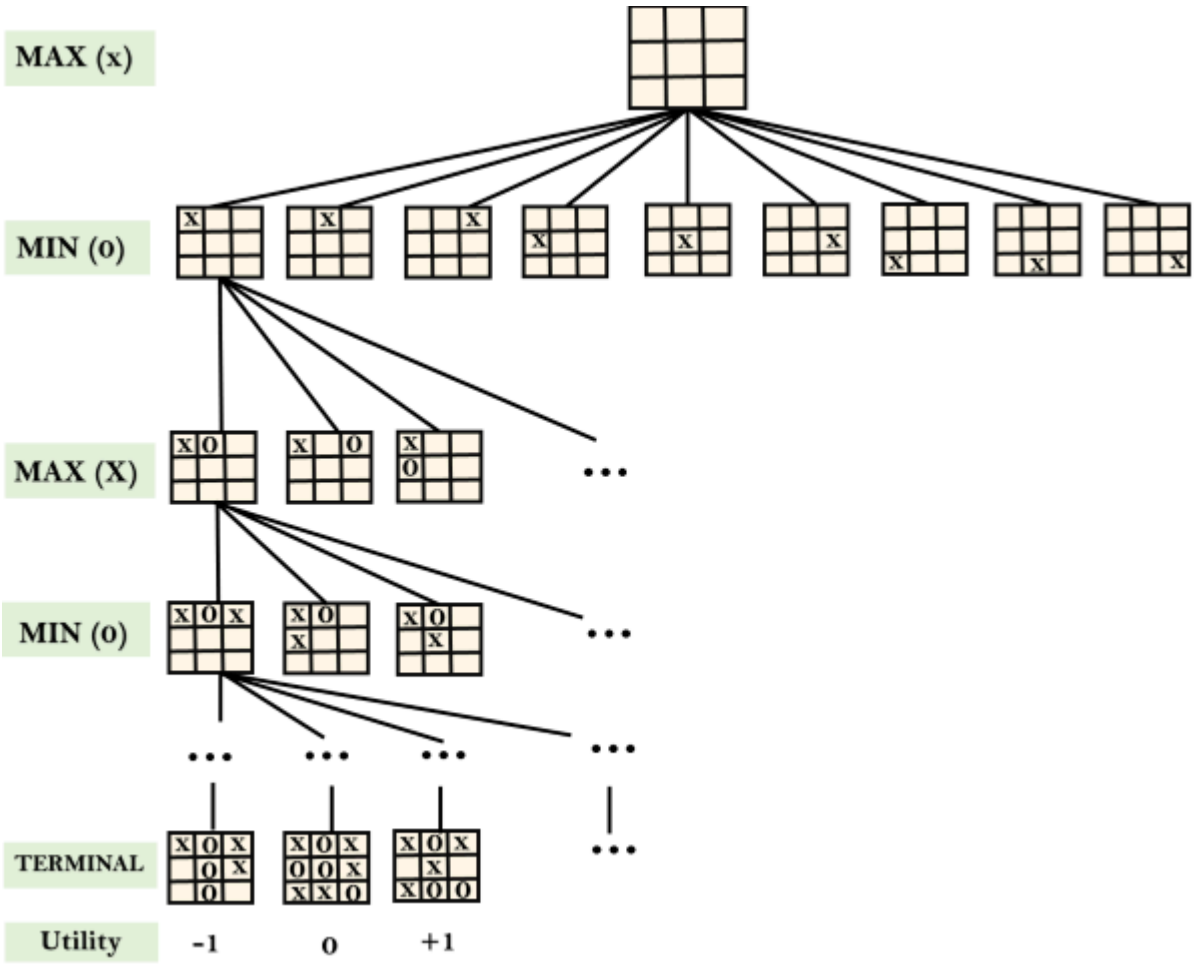
Game tree:

A game tree is a tree where nodes of the tree are the game states and Edges of the tree are the moves by players. Game tree involves initial state, actions function, and result Function.

Example: Tic-Tac-Toe game tree:

The following figure shows part of the game-tree for tic-tac-toe games. Following are some key points of the game:

- There are two players MAX and MIN.
- Players have an alternate turn and start with MAX.
- MAX maximizes the result of the game tree
- MIN minimizes the result.



Example Explanation:

- From the initial state, MAX has 9 possible moves as he starts first. MAX place x and MIN place o, and both players play alternatively until we reach a leaf node where one player has three in a row or all squares are filled.
- Both players will compute each node, minimax, the minimax value which is the best achievable utility against an optimal adversary.
- Suppose both the players are well aware of the tic-tac-toe and playing the best play. Each player is doing his best to prevent another one from winning. MIN is acting against Max in the game.
- So in the game tree, we have a layer of Max, a layer of MIN, and each layer is called as **Ply**. Max places x, then MIN puts on to prevent Max from winning, and this game continues until the terminal node.
- In this either MIN wins, MAX wins, or it's a draw. This game-tree is the whole search space of possibilities that MIN and MAX are playing tic-tac-toe and taking turns alternately.

Hence adversarial Search for the minimax procedure works as follows:

- It aims to find the optimal strategy for MAX to win the game.
- It follows the approach of Depth-first search.
- In the game tree, optimal leaf nodes could appear at any depth of the tree.
- Propagate the minimax values up to the tree until the terminal node is discovered.

In a given game tree, the optimal strategy can be determined from the minimax value of each node, which can be written as MINIMAX(n). MAX prefer to move to a state of maximum value and MIN prefer to move to a state of minimum value then:

For a state S MINIMAX(s) =

$$\begin{cases} \text{UTILITY}(s) & \text{If TERMINAL-TEST}(s) \\ \max_{a \in \text{Actions}(s)} \text{MINIMAX}(\text{RESULT}(s, a)) & \text{If PLAYER}(s) = \text{MAX} \\ \min_{a \in \text{Actions}(s)} \text{MINIMAX}(\text{RESULT}(s, a)) & \text{If PLAYER}(s) = \text{MIN}. \end{cases}$$

Mini-Max Algorithm in Artificial Intelligence

- Mini-max algorithm is a recursive or backtracking algorithm which is used in decision-making and game theory. It provides an optimal move for the player assuming that the opponent is also playing optimally.
- The Mini-Max algorithm uses recursion to search through the game-tree.
- The Min-Max algorithm is mostly used for game playing in AI. Such as Chess, Checkers, tic-tac-toe, go, and various two-players games. This Algorithm computes the minimax decision for the current state.
- In this algorithm two players play the game, one is called MAX and other is called MIN.
- Both the players fight it as the opponent player gets the minimum benefit while they get the maximum benefit.
- Both Players of the game are opponents of each other, where MAX will select the maximized value and MIN will select the minimized value.
- The minimax algorithm performs a depth-first search algorithm for the exploration of the complete game tree.
- The minimax algorithm proceeds all the way down to the terminal node of the tree, then backtrack the tree as the recursion.

Pseudo-code for MinMax Algorithm:

```
function minimax(node, depth, maximizingPlayer) is
if depth ==0 or node is a terminal node then
return static evaluation of node

if MaximizingPlayer then     // for Maximizer Player
maxEva= -infinity
 for each child of node do
 eva= minimax(child, depth-1, false)
maxEva= max(maxEva,eva)      //gives Maximum of the values
return maxEva

else                 // for Minimizer player
 minEva= +infinity
 for each child of node do
 eva= minimax(child, depth-1, true)
 minEva= min(minEva, eva)      //gives minimum of the values
 return minEva
```

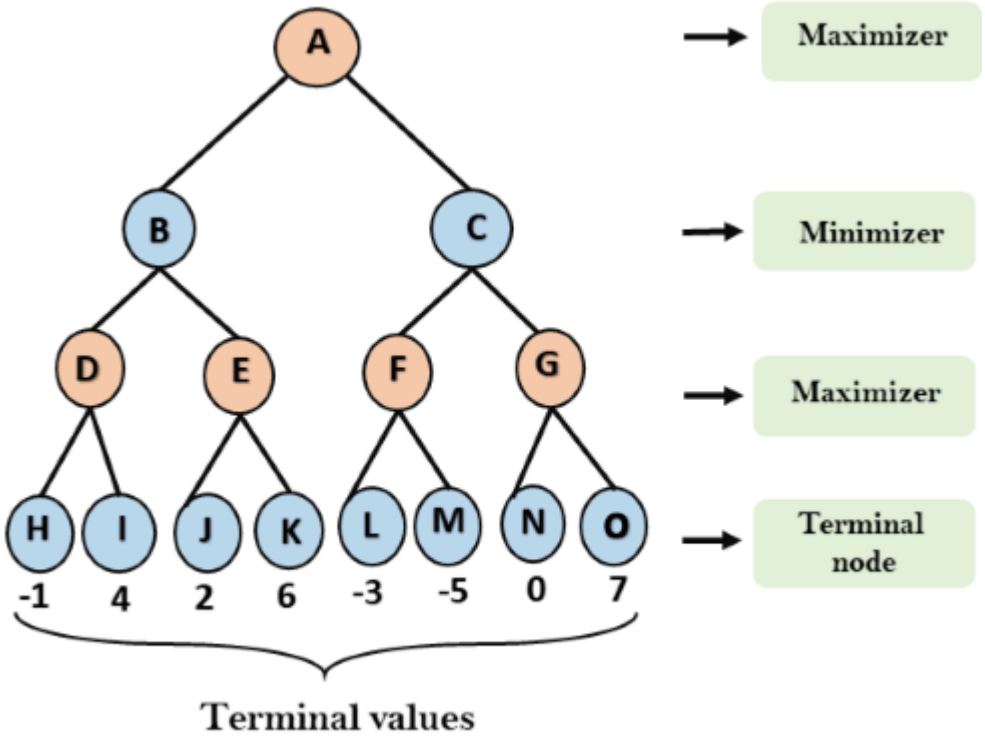
Initial call:

Minimax(node, 3, true)

Working of Min-Max Algorithm:

- The working of the minimax algorithm can be easily described using an example. Below we have taken an example of game-tree which is representing the two-player game.
- In this example, there are two players one is called Maximizer and other is called Minimizer.
- Maximizer will try to get the Maximum possible score, and Minimizer will try to get the minimum possible score.
- This algorithm applies DFS, so in this game-tree, we have to go all the way through the leaves to reach the terminal nodes.
- At the terminal node, the terminal values are given so we will compare those values and backtrack the tree until the initial state occurs. Following are the main steps involved in solving the two-player game tree:

Step-1: In the first step, the algorithm generates the entire game-tree and apply the utility function to get the utility values for the terminal states. In the below tree diagram, let's take A as the initial state of the tree. Suppose maximizer takes the first turn which has worst-case initial value =- infinity, and minimizer takes the next turn which has worst-case initial value = +infinity.

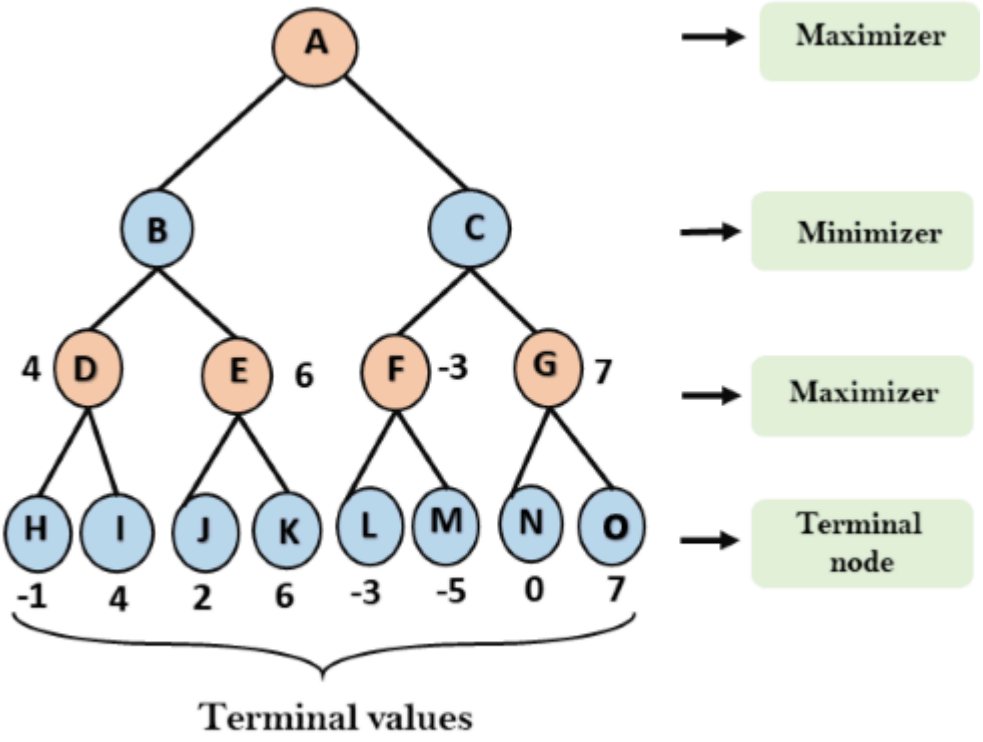


Step 2: Now, first we find the utilities value for the Maximizer, its initial value is -∞, so we will compare each value in terminal state with initial value of Maximizer and determines the higher nodes values. It will find the maximum among them all.

Stay

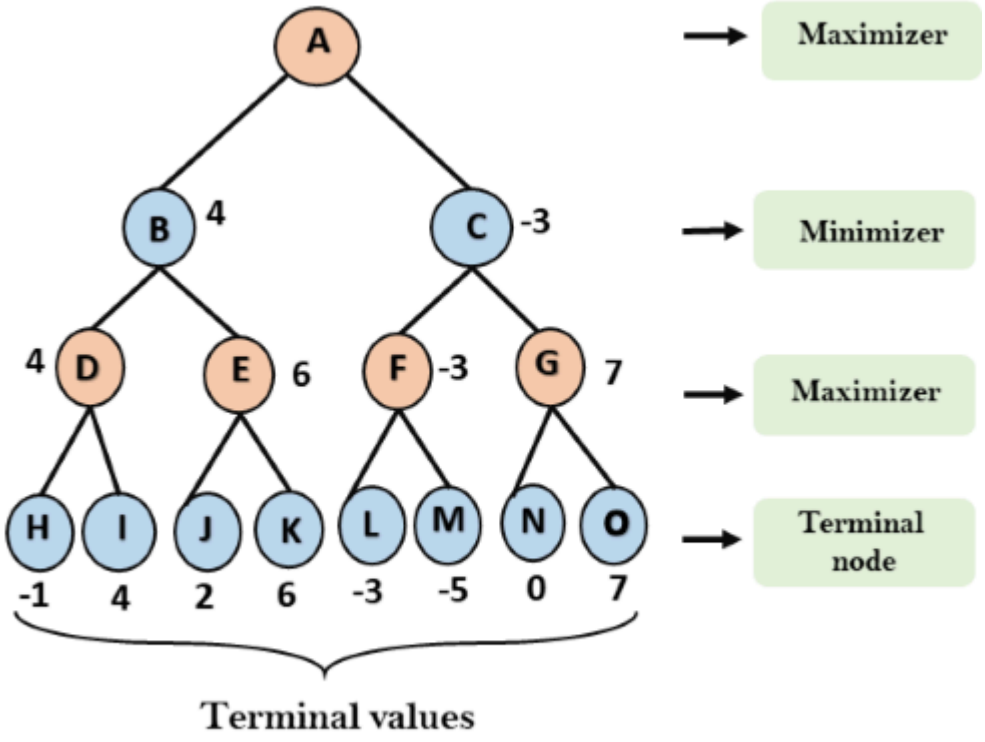
- For node D max(-1,- -∞) => max(-1,4)= 4

- For Node E max(2, -∞) => max(2, 6)= 6
- For Node F max(-3, -∞) => max(-3,-5) = -3
- For node G max(0, -∞) = max(0, 7) = 7



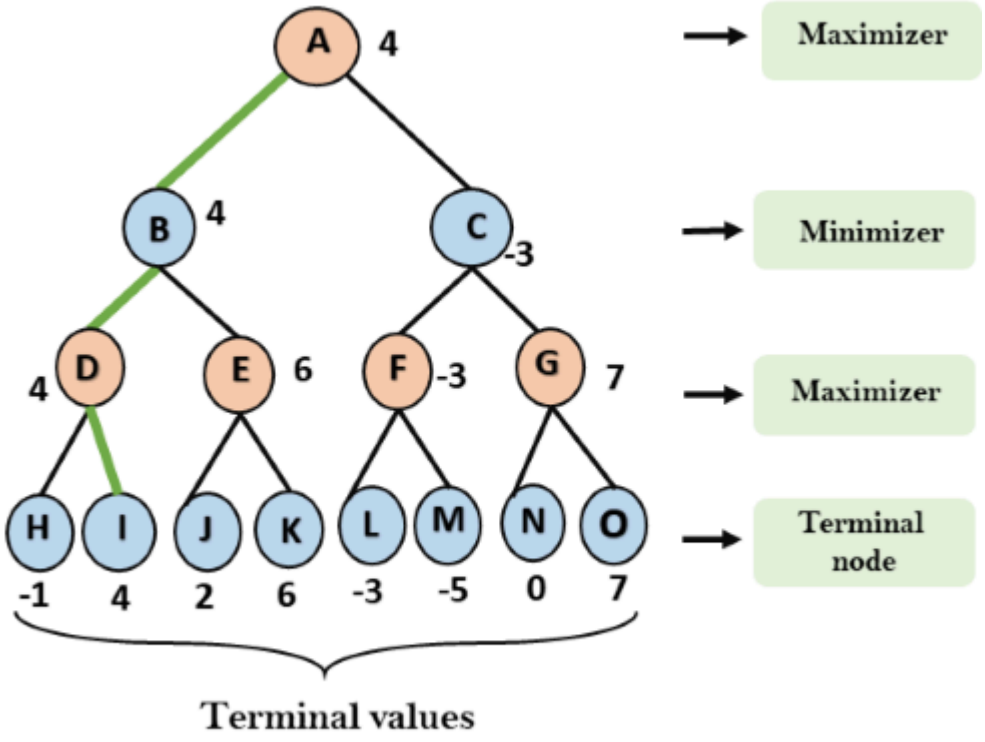
Step 3: In the next step, it's a turn for minimizer, so it will compare all nodes value with +∞, and will find the 3rd layer node values.

- For node B= min(4,6) = 4
- For node C= min (-3, 7) = -3



Step 4: Now it's a turn for Maximizer, and it will again choose the maximum of all nodes value and find the maximum value for the root node. In this game tree, there are only 4 layers, hence we reach immediately to the root node, but in real games, there will be more than 4 layers.

- For node A max(4, -3)= 4



That was the complete workflow of the minimax two player game.

Properties of Minimax algorithm:

- **Complete-** Min-Max algorithm is Complete. It will definitely find a solution (if it exists), in the finite search tree.
- **Optimal-** Min-Max algorithm is optimal if both opponents are playing optimally.
- **Time complexity-** As it performs DFS for the game-tree, so the time complexity of Min-Max algorithm is **$O(b^m)$**, where b is branching factor of the game-tree, and m is the maximum depth of the tree.
- **Space Complexity-** Space complexity of Minimax algorithm is also similar to DFS which is **O(bm)**.

Limitation of the minimax Algorithm:

The main drawback of the minimax algorithm is that it gets really slow for complex games such as Chess, go, etc. This type of game has a huge branching factor, and the player has lots of choices to decide. This limitation of the minimax algorithm can be improved from **alpha-beta pruning** which we have discussed in the next topic.

Alpha-Beta Pruning

- Alpha-beta pruning is a modified version of the minimax algorithm. It is an optimization technique for the minimax algorithm.
- As we have seen in the minimax search algorithm, the number of game states it has to examine are exponential in depth of the tree. Since we cannot eliminate the exponent, but we can cut it to half. Hence there is a technique by which without checking each node of the game tree we can compute the correct minimax decision, and this technique is called **pruning**. This involves two threshold parameter Alpha and beta for future expansion, so it is called **alpha-beta pruning**. It is also called as **Alpha-Beta Algorithm**.

- Alpha-beta pruning can be applied at any depth of a tree, and sometimes it not only prunes the tree leaves but also the entire sub-tree.
- The two-parameter can be defined as:

    a. **Alpha:** The best (highest-value) choice we have found so far at any point along the path of Maximizer. The initial value of alpha is **-∞**.

    a. **Beta:** The best (lowest-value) choice we have found so far at any point along the path of Minimizer. The initial value of beta is **+∞**.

The Alpha-beta pruning to a standard minimax algorithm returns the same move as the standard algorithm does, but it removes all the nodes which are not really affecting the final decision but making the algorithm slow. Hence by pruning these nodes, it makes the algorithm fast.

Note: To better understand this topic, kindly study the minimax algorithm.

Condition for Alpha-beta pruning:

The main condition which required for alpha-beta pruning is:

α>=β

Key points about alpha-beta pruning:

- The Max player will only update the value of alpha.
- The Min player will only update the value of beta.
- While backtracking the tree, the node values will be passed to upper nodes instead of values of alpha and beta.
- We will only pass the alpha, beta values to the child nodes.

Pseudo-code for Alpha-beta Pruning:

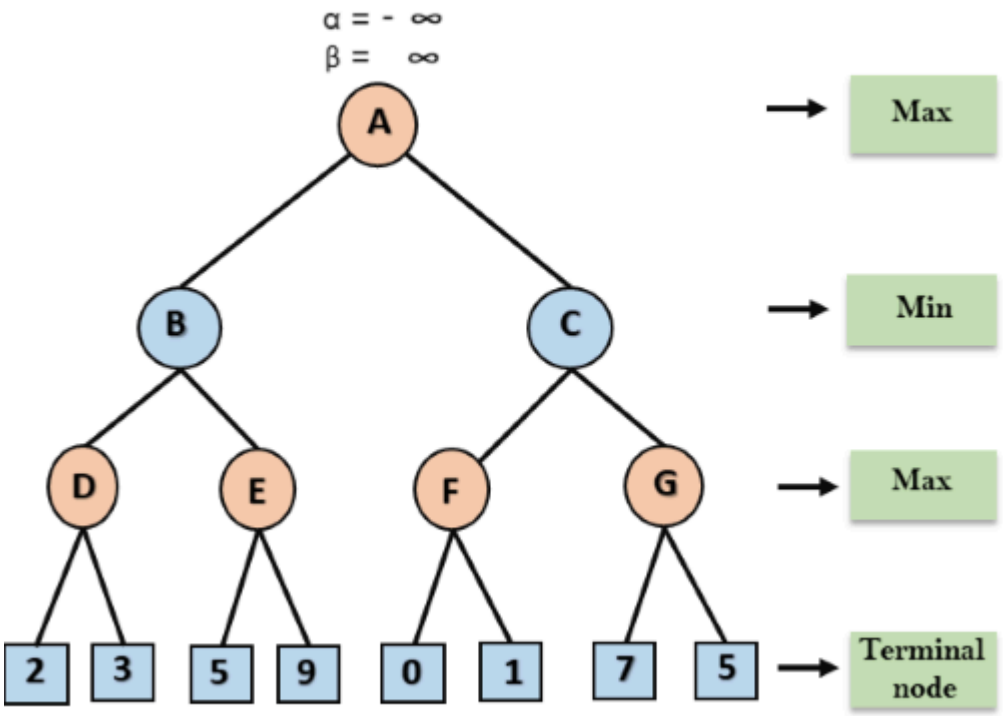
```
function minimax(node, depth, alpha, beta, maximizingPlayer) is
if depth ==0 or node is a terminal node then
return static evaluation of node

if MaximizingPlayer then      // for Maximizer Player
   maxEva= -infinity
   for each child of node do
   eva= minimax(child, depth-1, alpha, beta, False)
   maxEva= max(maxEva, eva)
   alpha= max(alpha, maxEva)
   if beta<=alpha
   break
   return maxEva

else                 // for Minimizer player
   minEva= +infinity
   for each child of node do
   eva= minimax(child, depth-1, alpha, beta, true)
   minEva= min(minEva, eva)
```

```
0.    beta= min(beta, eva)
1.     if beta<=alpha
2.    break
3.  return minEva
```

Working of Alpha-Beta Pruning:

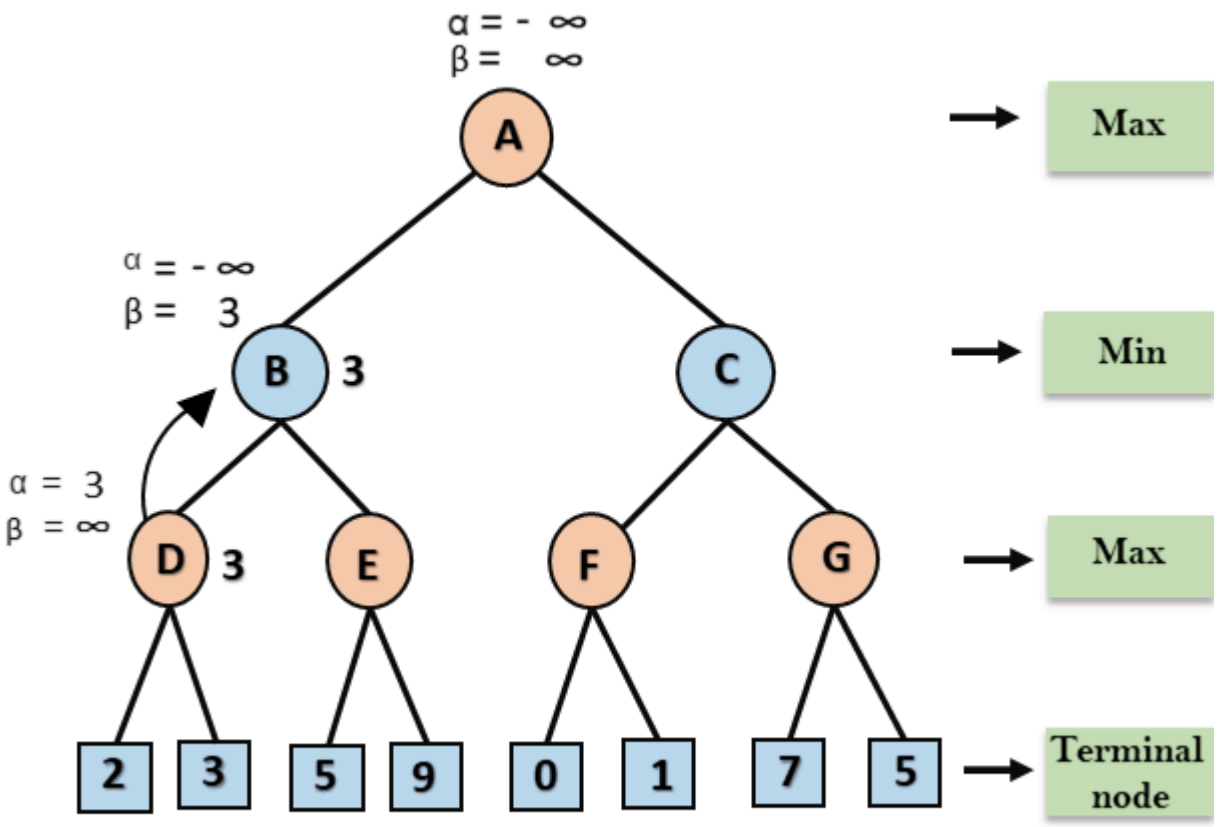
Let's take an example of two-player search tree to understand the working of Alpha-beta pruning

Step 1: At the first step the, Max player will start first move from node A where α= -∞ and β= +∞, these value of alpha and beta passed down to node B where again α= -∞ and β= +∞, and Node B passes the same value to its child D.



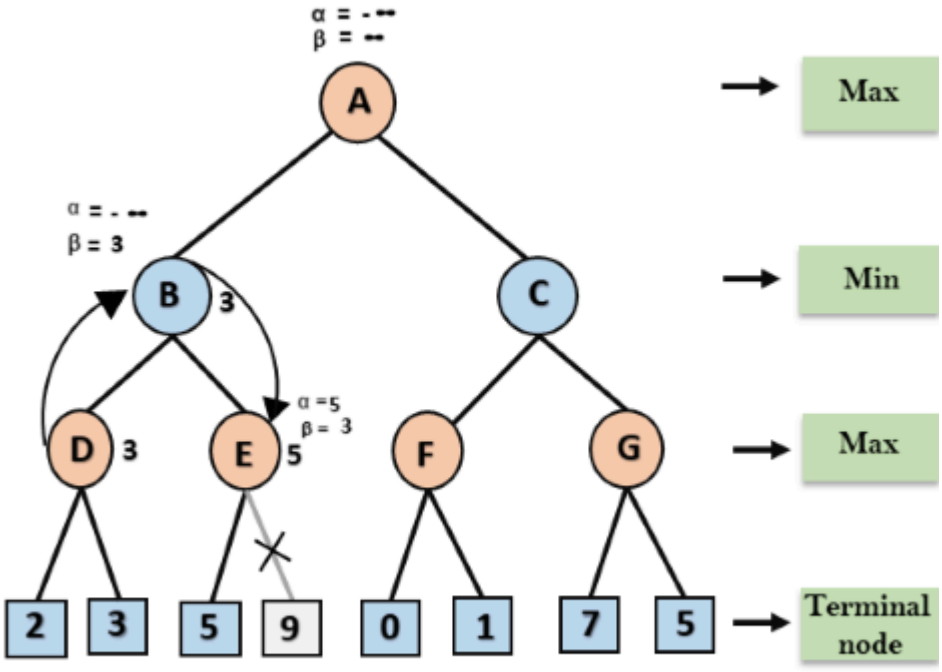
Step 2: At Node D, the value of α will be calculated as its turn for Max. The value of α is compared with firstly 2 and then 3, and the max (2, 3) = 3 will be the value of α at node D and node value will also be 3.

Step 3: Now algorithm backtrack to node B, where the value of β will change as this is a turn of Min, Now β= +∞, will compare with the available subsequent nodes value, i.e. min (∞, 3) = 3, hence at node B now α= -∞, and β= 3.



In the next step, the algorithm traverses the next successor of Node B which is node E, and the values of α= -∞, and β= 3 will also be passed.

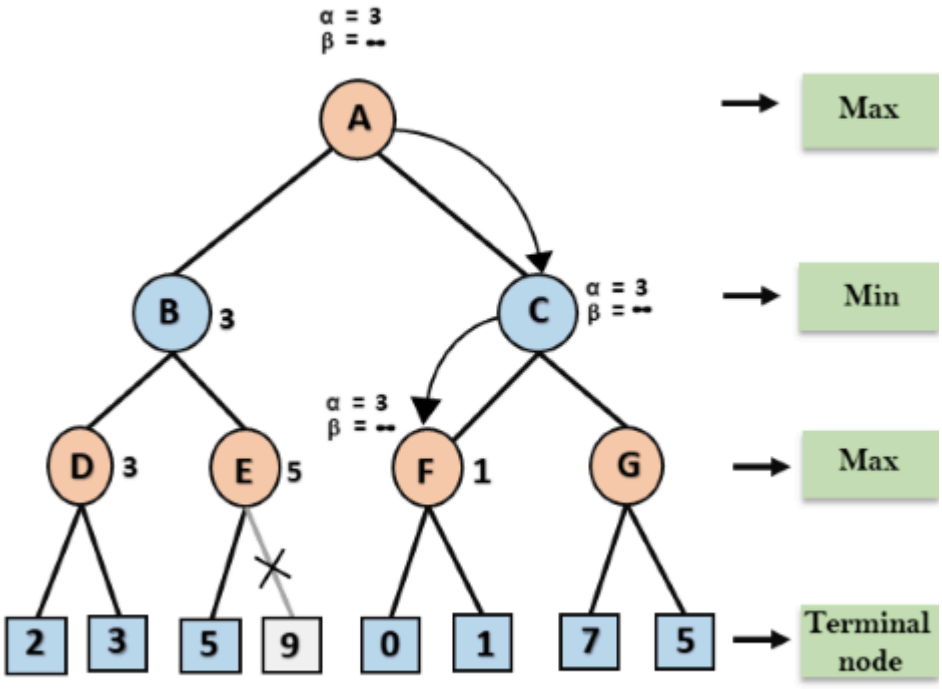
Step 4: At node E, Max will take its turn, and the value of alpha will change. The current value of alpha will be compared with 5, so max (-∞, 5) = 5, hence at node E α= 5 and β= 3, where α>=β, so the right successor of E will be pruned, and algorithm will not traverse it, and the value at node E will be 5.



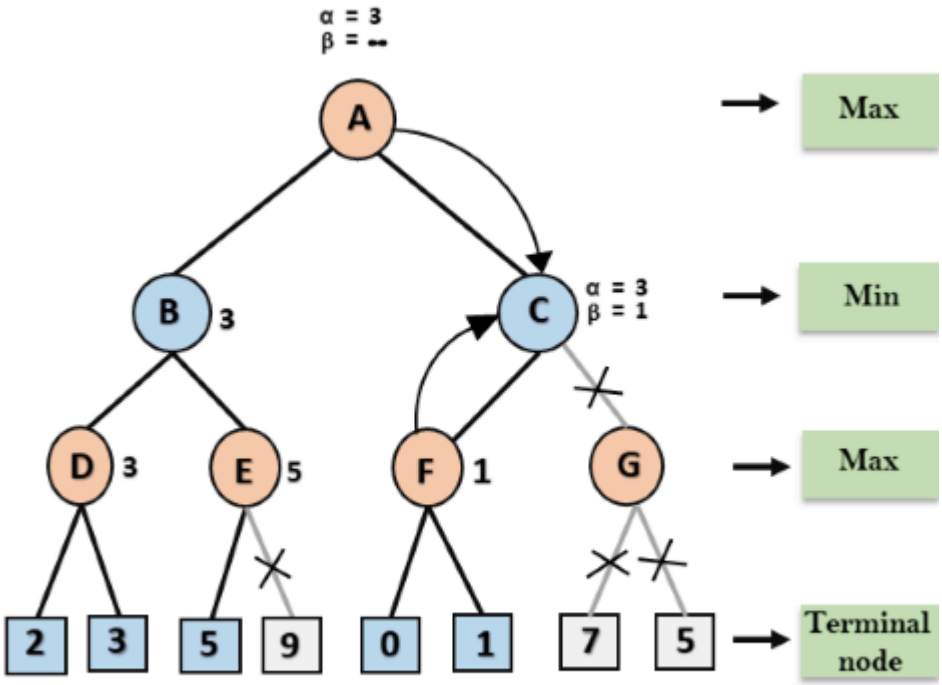
Step 5: At next step, algorithm again backtrack the tree, from node B to node A. At node A, the value of alpha will be changed the maximum available value is 3 as max (-∞, 3)= 3, and β= +∞, these two values now passes to right successor of A which is Node C.

At node C, α=3 and β= +∞, and the same values will be passed on to node F.

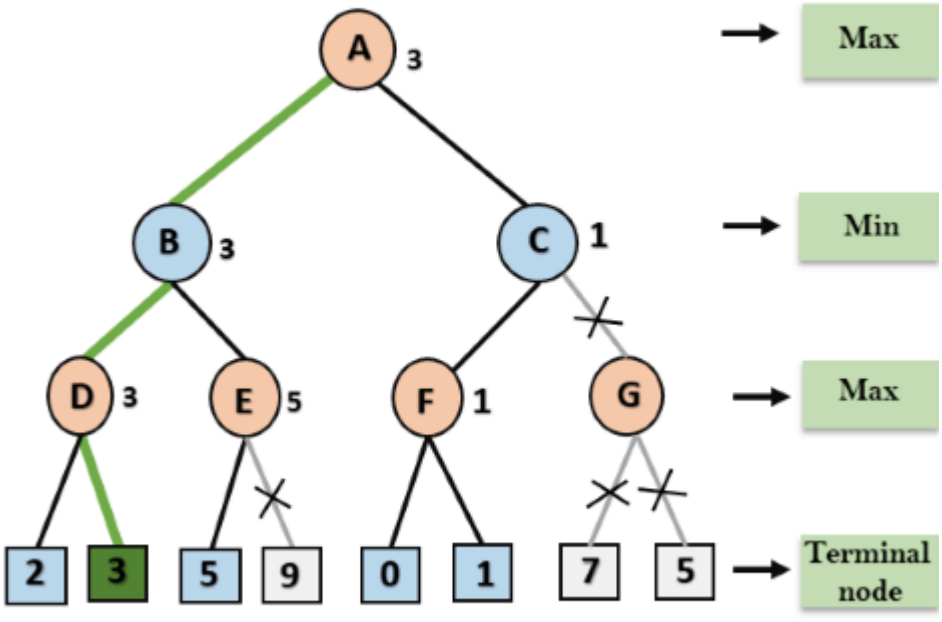
Step 6: At node F, again the value of α will be compared with left child which is 0, and max(3,0)= 3, and then compared with right child which is 1, and max(3,1)= 3 still α remains 3, but the node value of F will become 1.



Step 7: Node F returns the node value 1 to node C, at C α= 3 and β= +∞, here the value of beta will be changed, it will compare with 1 so min (∞, 1) = 1. Now at C, α=3 and β= 1, and again it satisfies the condition α>=β, so the next child of C which is G will be pruned, and the algorithm will not compute the entire subtree G.



Step 8: C now returns the value of 1 to A here the best value for A is max (3, 1) = 3. Following is the final game tree which shows the nodes which are computed and nodes which have never been computed. Hence the optimal value for the maximizer is 3 for this example.



Move Ordering in Alpha-Beta pruning:

The effectiveness of alpha-beta pruning is highly dependent on the order in which each node is examined. Move order is an important aspect of alpha-beta pruning.

It can be of two types:

- **Worst ordering:** In some cases, alpha-beta pruning algorithm does not prune any of the leaves of the tree, and works exactly as minimax algorithm. In this case, it also consumes more time because of alpha-beta factors, such a move of pruning is called worst ordering. In this case, the best move occurs on the right side of the tree. The time complexity for such an order is $O(b^m)$.
- **Ideal ordering:** The ideal ordering for alpha-beta pruning occurs when lots of pruning happens in the tree, and best moves occur at the left side of the tree. We apply DFS, hence it first searches left of the tree and goes deep twice as a minimax algorithm in the same amount of time. Complexity in ideal ordering is $O(b^{m/2})$.

Rules to find good ordering:

Following are some rules to find good ordering in alpha-beta pruning:

- Occur the best move from the shallowest node.
- Order the nodes in the tree such that the best nodes are checked first.
- Use domain knowledge while finding the best move. Ex: for Chess, try order: captures first, then threats, then forward moves, backward moves.
- We can bookkeep the states, as there is a possibility that states may repeat.

What are Expert Systems?

An expert system is a computer program that is designed to solve complex problems and to provide decision-making ability like a human expert. It performs this by extracting knowledge from its knowledge base using the reasoning and inference rules according to the user queries.

The expert system is a part of AI, and the first ES was developed in the year 1970, which was the first successful approach of artificial intelligence. It solves the most complex issue as an expert by extracting the knowledge stored in its knowledge base. The system helps in decision making for complex problems using **both facts and heuristics like a human expert**. It is called so because it contains the expert knowledge of a specific domain and can solve any complex problem of that particular domain. These systems are designed for a specific domain, such as **medicine, science,** etc.

The performance of an expert system is based on the expert's knowledge stored in its knowledge base. The more knowledge stored in the KB, the more that system improves its performance. One of the common examples of an ES is a suggestion of spelling errors while typing in the Google search box.

The expert systems are the computer applications developed to solve complex problems in a particular domain, at the level of extra-ordinary human intelligence and expertise.

Below are some popular examples of the Expert System:

- **DENDRAL:** It was an artificial intelligence project that was made as a chemical analysis expert system. It was used in organic chemistry to detect unknown organic molecules with the help of their mass spectra and knowledge base of chemistry.
- **MYCIN:** It was one of the earliest backward chaining expert systems that was designed to find the bacteria causing infections like bacteraemia and meningitis. It was also used for the recommendation of antibiotics and the diagnosis of blood clotting diseases.
- **PXDES:** It is an expert system that is used to determine the type and level of lung cancer. To determine the disease, it takes a picture from the upper body, which looks like the shadow. This shadow identifies the type and degree of harm.
- **CaDeT:** The CaDet expert system is a diagnostic support system that can detect cancer at early stages.

Characteristics of Expert Systems

- High performance
- Understandable
- Reliable
- Highly responsive
- **High Performance:** The expert system provides high performance for solving any type of complex problem of a specific domain with high efficiency and accuracy.
- **Understandable:** It responds in a way that can be easily understandable by the user. It can take input in human language and provide the output in the same way.
- **Reliable:** It is much reliable for generating an efficient and accurate output.
- **Highly responsive:** ES provides the result for any complex query within a very short period of time.

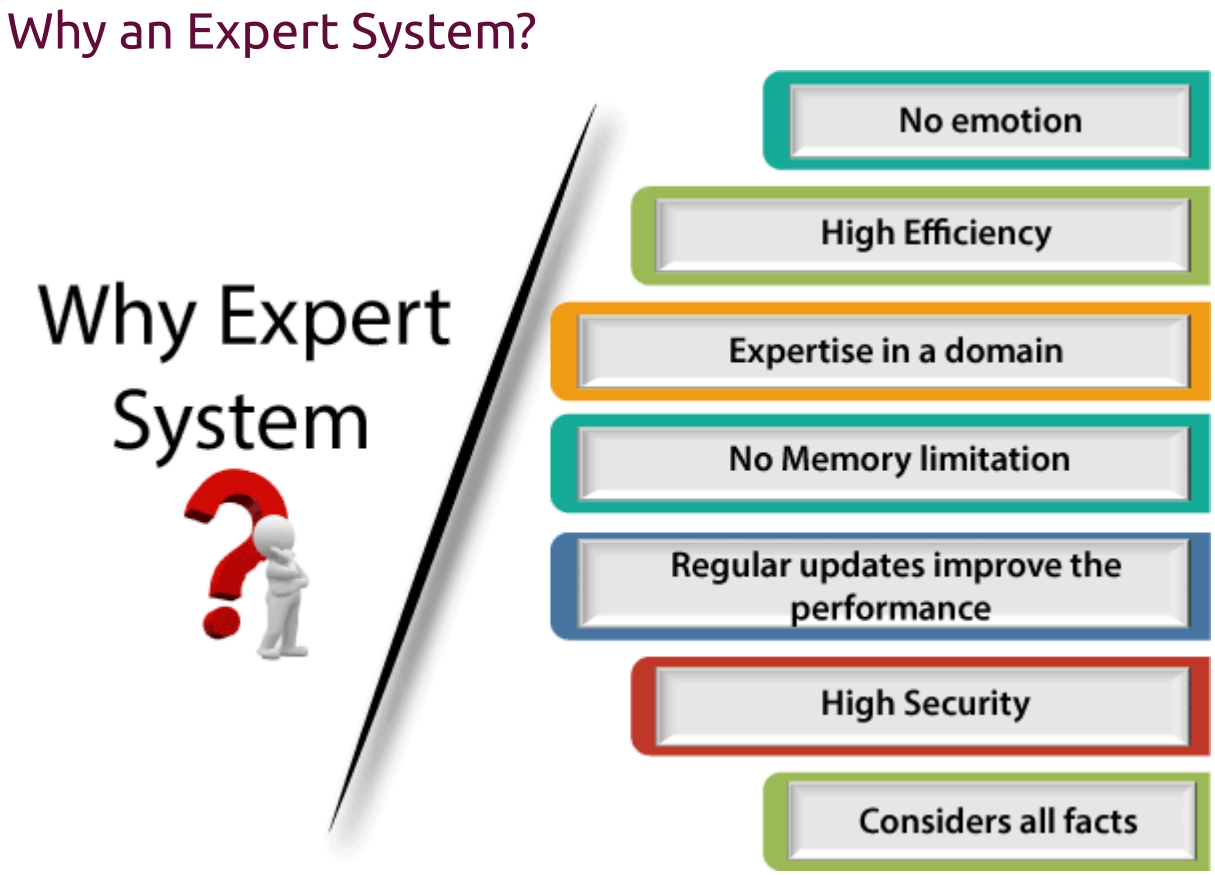
Capabilities of the Expert System

Below are some capabilities of an Expert System:

- **Advising:** It is capable of advising the human being for the query of any domain from the particular ES.
- **Provide decision-making capabilities:** It provides the capability of decision making in any domain, such as for making any financial decision, decisions in medical science, etc.
- **Demonstrate a device:** It is capable of demonstrating any new products such as its features, specifications, how to use that product, etc.
- **Problem-solving:** It has problem-solving capabilities.
- **Explaining a problem:** It is also capable of providing a detailed description of an input problem.
- **Interpreting the input:** It is capable of interpreting the input given by the user.
- **Predicting results:** It can be used for the prediction of a result.
- **Diagnosis:** An ES designed for the medical field is capable of diagnosing a disease without using multiple components as it already contains various inbuilt medical tools.

Benefits of Expert Systems

- **Availability** – They are easily available due to mass production of software.
- **Less Production Cost** – Production cost is reasonable. This makes them affordable.
- **Speed** – They offer great speed. They reduce the amount of work an individual puts in.
- **Less Error Rate** – Error rate is low as compared to human errors.
- **Reducing Risk** – They can work in the environment dangerous to humans.
- **Steady response** – They work steadily without getting emotional, tensed or fatigued.



So below are the points that are describing the need of the ES:

1. **No memory Limitations:** It can store as much data as required and can memorize it at the time of its application. But for human experts, there are some limitations to memorizing all things at all times.
2. **High Efficiency:** If the knowledge base is updated with the correct knowledge, then it provides a highly efficient output, which may not be possible for a human.
3. **Expertise in a domain:** There are lots of human experts in each domain, and they all have different skills, different experiences, and different skills, so it is not easy to get a final output for the query. But

if we put the knowledge gained from human experts into the expert system, then it provides an efficient output by mixing all the facts and knowledge

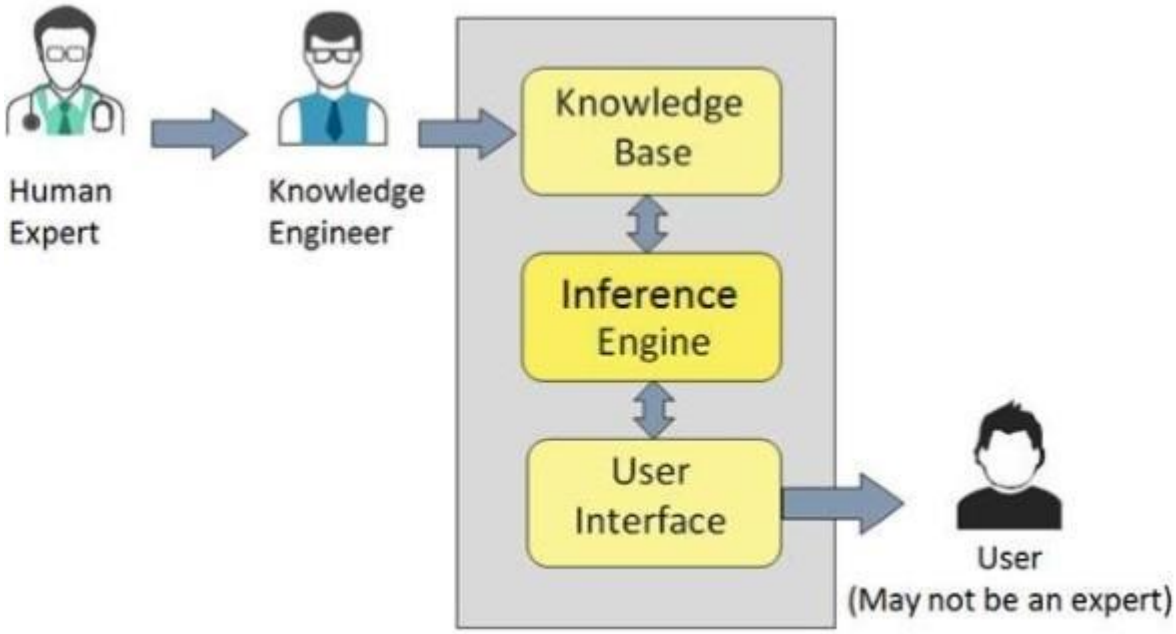
4. **Not affected by emotions:** These systems are not affected by human emotions such as fatigue, anger, depression, anxiety, etc.. Hence the performance remains constant.
5. **High security:** These systems provide high security to resolve any query.
6. **Considers all the facts:** To respond to any query, it checks and considers all the available facts and provides the result accordingly. But it is possible that a human expert may not consider some facts due to any reason.
7. **Regular updates improve the performance:** If there is an issue in the result provided by the expert systems, we can improve the performance of the system by updating the knowledge base

Components of Expert Systems

The components of ES include –

- Knowledge Base
- Inference Engine
- User Interface

Let us see them one by one briefly –



Knowledge Base

It contains domain-specific and high-quality knowledge.

Knowledge is required to exhibit intelligence. The success of any ES majorly depends upon the collection of highly accurate and precise knowledge.

What is Knowledge?

The data is a collection of facts. The information is organized as data and facts about the task domain. **Data, information,** and **past experience** combined together are termed as knowledge.

Components of Knowledge Base

- The knowledgebase is a type of storage that stores knowledge acquired from the different experts of the particular domain. It is considered as a big storage of knowledge. The more the knowledge base, the more precise will be the Expert System.
- It is similar to a database that contains information and rules of a particular domain or subject.
- One can also view the knowledge base as collections of objects and their attributes. Such as a Lion is an object and its attributes are it is a mammal, it is not a domestic animal, etc.

The knowledge base of an ES is a store of both factual and heuristic knowledge.

- **Factual Knowledge** – It is the information widely accepted by the Knowledge Engineers and scholars in the task domain.
- **Heuristic Knowledge** – It is about practice, accurate judgement, one's ability of evaluation, and guessing.

Knowledge representation

It is used to formalize the knowledge stored in the knowledge base using the If-else rules.

It is the method used to organize and formalize the knowledge in the knowledge base. It is in the form of IF-THEN-ELSE rules.

Knowledge Acquisition

It is the process of extracting, organizing, and structuring the domain knowledge, specifying the rules to acquire the knowledge from various experts, and storing that knowledge into the knowledge base.

The success of any expert system majorly depends on the quality, completeness, and accuracy of the information stored in the knowledge base.

The knowledge base is formed by readings from various experts, scholars, and the **Knowledge Engineers**. The knowledge engineer is a person with the qualities of empathy, quick learning, and case analyzing skills.

He acquires information from subject experts by recording, interviewing, and observing him at work, etc. He then categorizes and organizes the information in a meaningful way, in the form of IF-THEN-ELSE rules, to be used by an interference machine. The knowledge engineer also monitors the development of the ES.

Inference Engine

- The inference engine is known as the brain of the expert system as it is the main processing unit of the system. It applies inference rules to the knowledge base to derive a conclusion or deduce new information. It helps in deriving an error-free solution of queries asked by the user.
- With the help of an inference engine, the system extracts the knowledge from the knowledge base.
- There are two types of inference engine:
- **Deterministic Inference engine:** The conclusions drawn from this type of inference engine are assumed to be true. It is based on **facts** and **rules**.
- **Probabilistic Inference engine:** This type of inference engine contains uncertainty in conclusions, and based on the probability.

Use of efficient procedures and rules by the Inference Engine is essential in deducting a correct, flawless solution.

In case of knowledge-based ES, the Inference Engine acquires and manipulates the knowledge from the knowledge base to arrive at a particular solution.

In case of rule based ES, it –

- Applies rules repeatedly to the facts, which are obtained from earlier rule application.
- Adds new knowledge into the knowledge base if required.
- Resolves rules conflict when multiple rules are applicable to a particular case.

To recommend a solution, the Inference Engine uses the following strategies –

- Forward Chaining
- Backward Chaining

Inference engine uses the below modes to derive the solutions:

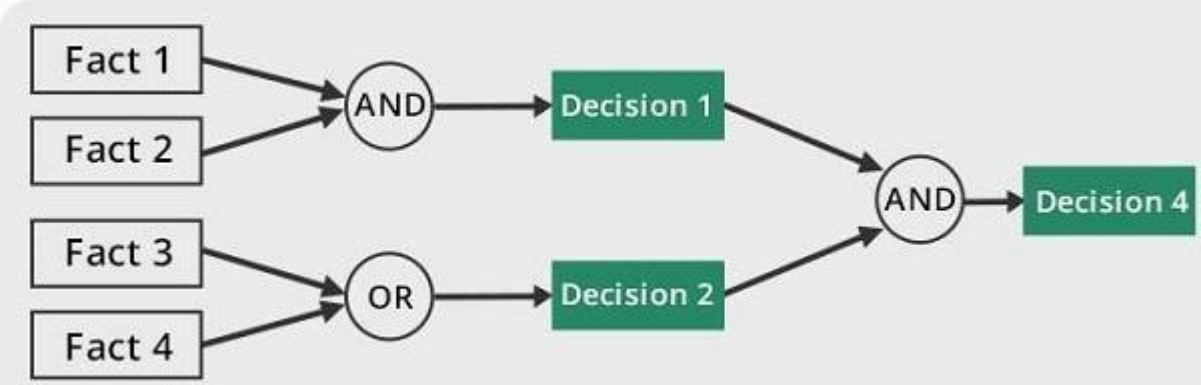
- **Forward Chaining:** It starts from the known facts and rules, and applies the inference rules to add their conclusion to the known facts.
- **Backward Chaining:** It is a backward reasoning method that starts from the goal and works backward to prove the known facts.

Forward Chaining

It is a strategy of an expert system to answer the question, **“What can happen next?”**

Here, the Inference Engine follows the chain of conditions and derivations and finally deduces the outcome. It considers all the facts and rules, and sorts them before concluding to a solution.

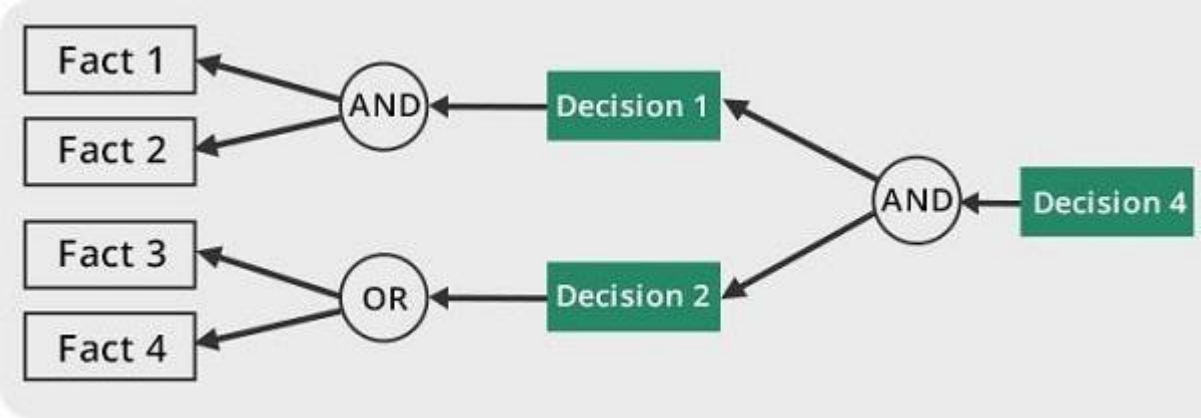
This strategy is followed for working on conclusion, result, or effect. For example, prediction of share market status as an effect of changes in interest rates.



Backward Chaining

With this strategy, an expert system finds out the answer to the question, **"Why this happened?"**

On the basis of what has already happened, the Inference Engine tries to find out which conditions could have happened in the past for this result. This strategy is followed for finding out cause or reason. For example, diagnosis of blood cancer in humans.



User Interface

User interface provides interaction between users of the ES and the ES itself. It is generally Natural Language Processing so as to be used by the user who is well-versed in the task domain. The user of the ES need not necessarily be an expert in Artificial Intelligence.

It explains how the ES has arrived at a particular recommendation. The explanation may appear in the following forms –

- Natural language displayed on screen.
- Verbal narrations in natural language.
- Listing of rule numbers displayed on the screen.

The user interface makes it easy to trace the credibility of the deductions.

Requirements of Efficient ES User Interface

- It should help users to accomplish their goals in the shortest possible way.
- It should be designed to work for user's existing or desired work practices.

- Its technology should be adaptable to user's requirements; not the other way round.
- It should make efficient use of user input.

Expert Systems Limitations

No technology can offer an easy and complete solution. Large systems are costly, require significant development time, and computer resources. ESs have their limitations which include –

- Limitations of the technology
- Difficult knowledge acquisition
- ES are difficult to maintain
- High development costs

Applications of Expert System

The following table shows where ES can be applied.

Application	Description
Design Domain	Camera lens design, automobile design.
Medical Domain	Diagnosis Systems to deduce cause of disease from observed data, conducting medical operations on humans.
Monitoring Systems	Comparing data continuously with observed systems or with prescribed behavior such as leakage monitoring in long petroleum pipelines.
Process Control Systems	Controlling a physical process based on monitoring.
Knowledge Domain	Finding faults in vehicles, computers.
Finance/Commerce	Detection of possible fraud, suspicious transactions, stock market trading, Airline scheduling, cargo scheduling.

Expert System Technology

There are several levels of ES technologies available. Expert systems technologies include –

- **Expert System Development Environment** – The ES development environment includes hardware and tools. They are –
  - Workstations, minicomputers, mainframes.
  - High level Symbolic Programming Languages such as **LIS**t **P**rogramming (LISP) and **PRO**grammation en **LOG**ique (PROLOG).
  - Large databases.
- **Tools** – They reduce the effort and cost involved in developing an expert system to large extent.
  - Powerful editors and debugging tools with multi-windows.
  - They provide rapid prototyping
  - Have Inbuilt definitions of model, knowledge representation, and inference design.

- **Shells** – A shell is nothing but an expert system without knowledge base. A shell provides the developers with knowledge acquisition, inference engine, user interface, and explanation facility. For example, few shells are given below –
    - Java Expert System Shell (JESS) that provides fully developed Java API for creating an expert system.
    - *Vidwan*, a shell developed at the National Centre for Software Technology, Mumbai in 1993. It enables knowledge encoding in the form of IF-THEN rules.

Development of Expert Systems: General Steps

The process of ES development is iterative. Steps in developing the ES include –

Identify Problem Domain

- The problem must be suitable for an expert system to solve it.
- Find the experts in the task domain for the ES project.
- Establish cost-effectiveness of the system.

Design the System

- Identify the ES Technology
- Know and establish the degree of integration with the other systems and databases.
- Realize how the concepts can represent the domain knowledge best.

Develop the Prototype

From Knowledge Base: The knowledge engineer works to –

- Acquire domain knowledge from the expert.
- Represent it in the form of If-THEN-ELSE rules.

Test and Refine the Prototype

- The knowledge engineer uses sample cases to test the prototype for any deficiencies in performance.
- End users test the prototypes of the ES.

Develop and Complete the ES

- Test and ensure the interaction of the ES with all elements of its environment, including end users, databases, and other information systems.
- Document the ES project well.
- Train the user to use ES.

Maintain the System

- Keep the knowledge base up-to-date by regular review and update.
- Cater for new interfaces with other information systems, as those systems evolve.

Development of Expert System

Here, we will explain the working of an expert system by taking an example of MYCIN ES. Below are some steps to build an MYCIN:

- Firstly, ES should be fed with expert knowledge. In the case of MYCIN, human experts specialized in the medical field of bacterial infection, provide information about the causes, symptoms, and other knowledge in that domain.

- The KB of the MYCIN is updated successfully. In order to test it, the doctor provides a new problem to it. The problem is to identify the presence of the bacteria by inputting the details of a patient, including the symptoms, current condition, and medical history.
- The ES will need a questionnaire to be filled by the patient to know the general information about the patient, such as gender, age, etc.
- Now the system has collected all the information, so it will find the solution for the problem by applying if-then rules using the inference engine and using the facts stored within the KB.
- In the end, it will provide a response to the patient by using the user interface.

Participants in the development of Expert System

There are three primary participants in the building of Expert System:

1. **Expert:** The success of an ES much depends on the knowledge provided by human experts. These experts are those persons who are specialized in that specific domain.
2. **Knowledge Engineer:** Knowledge engineer is the person who gathers the knowledge from the domain experts and then codifies that knowledge to the system according to the formalism.
3. **End-User:** This is a particular person or a group of people who may not be experts, and working on the expert system needs the solution or advice for his queries, which are complex.

Advantages of Expert System

- These systems are highly reproducible.
- They can be used for risky places where the human presence is not safe.
- Error possibilities are less if the KB contains correct knowledge.
- The performance of these systems remains steady as it is not affected by emotions, tension, or fatigue.
- They provide a very high speed to respond to a particular query.

Limitations of Expert System

- The response of the expert system may get wrong if the knowledge base contains the wrong information.
- Like a human being, it cannot produce a creative output for different scenarios.
- Its maintenance and development costs are very high.
- Knowledge acquisition for designing is very difficult.
- For each domain, we require a specific ES, which is one of the big limitations.
- It cannot learn from itself and hence requires manual updates.

Applications of Expert System

- **In designing and manufacturing domain**
  It can be broadly used for designing and manufacturing physical devices such as camera lenses and automobiles.
- **In the knowledge domain**
  These systems are primarily used for publishing the relevant knowledge to the users. The two popular ES used for this domain is an advisor and a tax advisor.
- **In the finance domain**
  In the finance industry, it is used to detect any type of possible fraud, suspicious activity, and advise bankers on whether they should provide loans for business or not.
- **In the diagnosis and troubleshooting of devices**
  In medical diagnosis, the ES system is used, and it was the first area where these systems were used.
- **Planning and Scheduling**
  The expert systems can also be used for planning and scheduling some particular tasks for achieving the goal of that task.

What are Artificial Neural Networks (ANNs)?

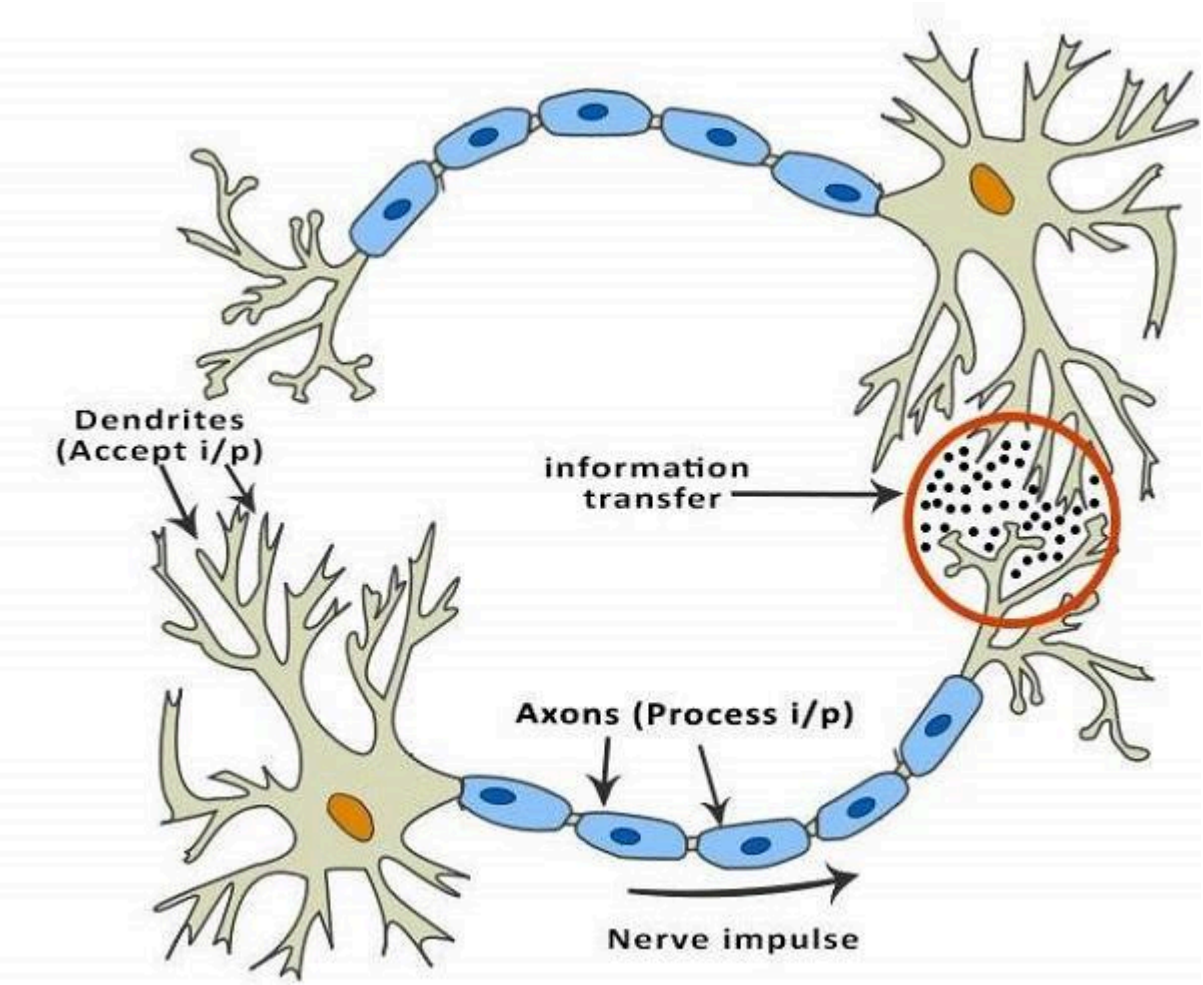
The inventor of the first neurocomputer, Dr. Robert Hecht-Nielsen, defines a neural network as –

"...a computing system made up of a number of simple, highly interconnected processing elements, which process information by their dynamic state response to external inputs."

Basic Structure of ANNs

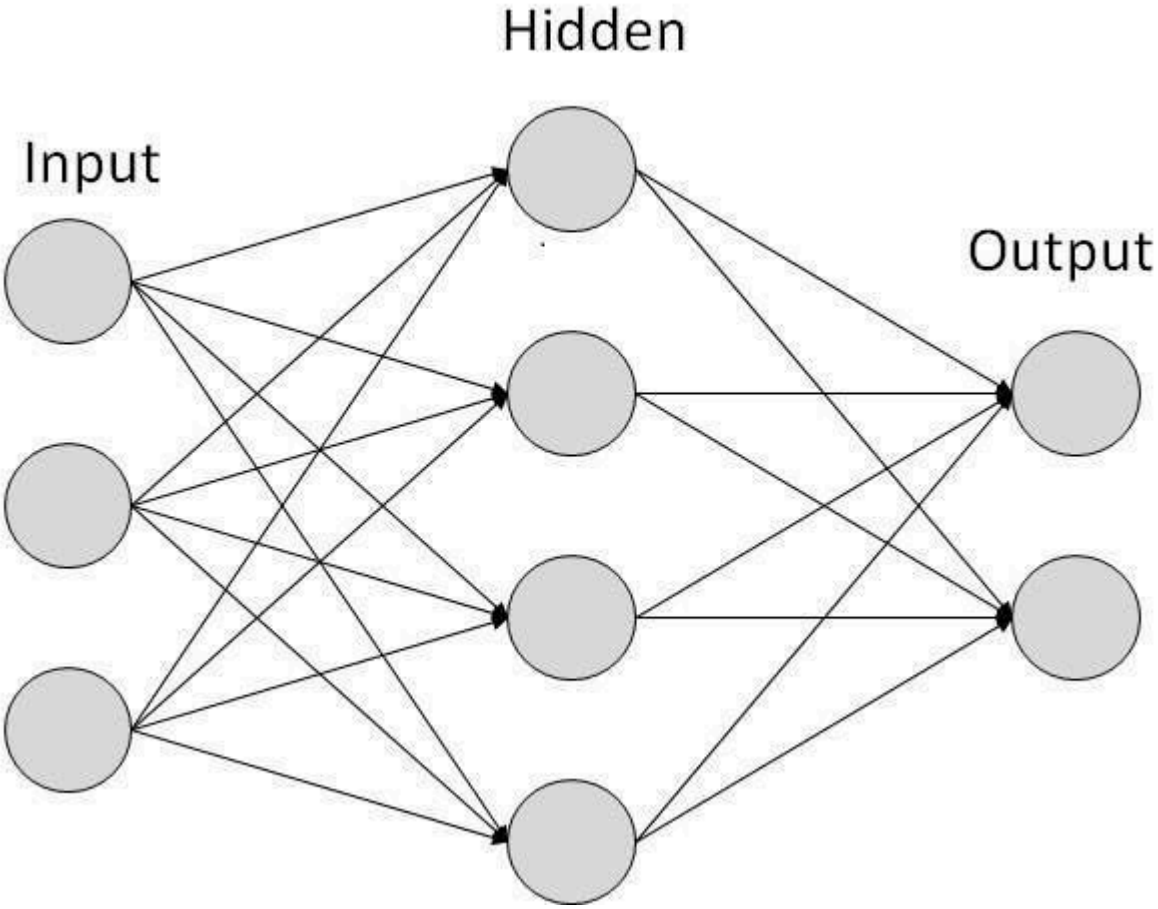
The idea of ANNs is based on the belief that working of human brain by making the right connections, can be imitated using silicon and wires as living **neurons** and **dendrites**.

The human brain is composed of 86 billion nerve cells called **neurons.** They are connected to other thousand cells by **Axons.** Stimuli from the external environment or inputs from sensory organs are accepted by dendrites. These inputs create electric impulses, which quickly travel through the neural network. A neuron can then send the message to another neuron to handle the issue or does not send it forward.



ANNs are composed of multiple **nodes**, which imitate biological **neurons** of human brain. The neurons are connected by links and they interact with each other. The nodes can take input data and perform simple operations on the data. The result of these operations is passed to other neurons. The output at each node is called its **activation** or **node value.**

Each link is associated with **weight.** ANNs are capable of learning, which takes place by altering weight values. The following illustration shows a simple ANN –

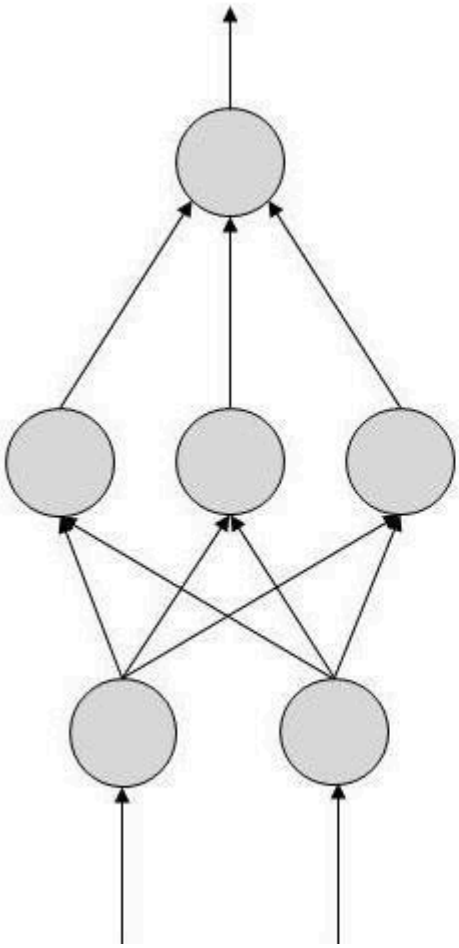


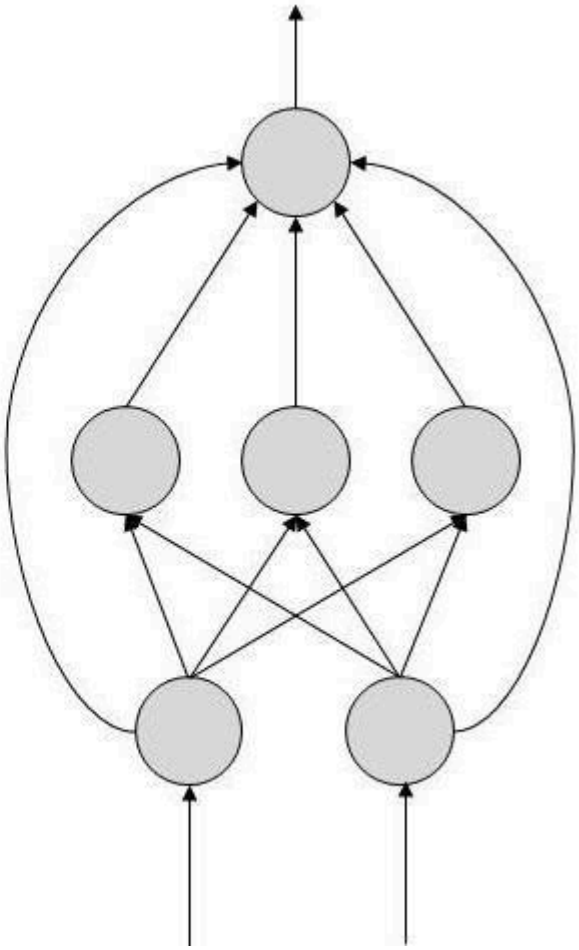
Types of Artificial Neural Networks

There are two Artificial Neural Network topologies – **FeedForward** and **Feedback.**

FeedForward ANN

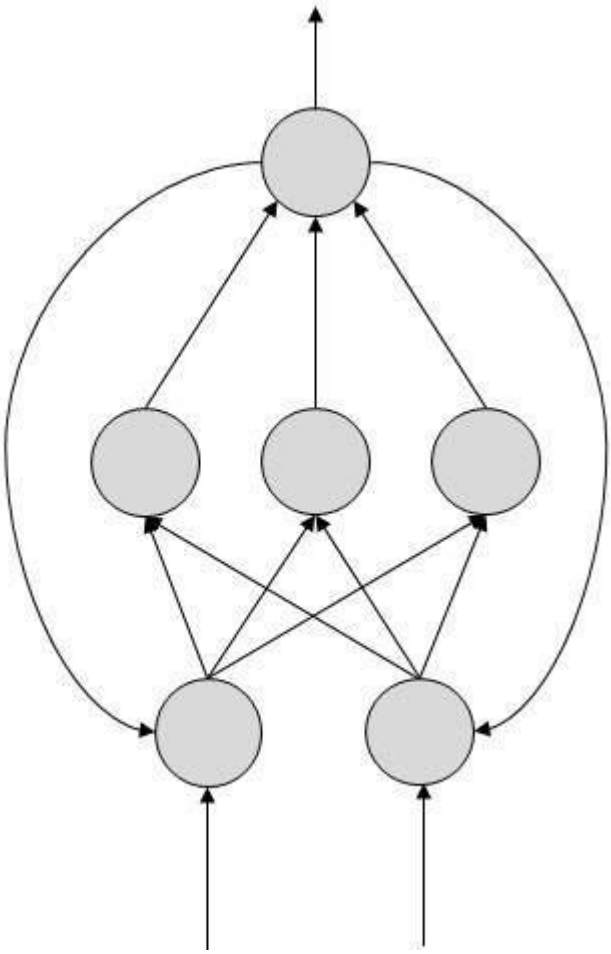
In this ANN, the information flow is unidirectional. A unit sends information to another unit from which it does not receive any information. There are no feedback loops. They are used in pattern generation/recognition/classification. They have fixed inputs and outputs.





FeedBack ANN

Here, feedback loops are allowed. They are used in content addressable memories.



Working of ANNs

In the topology diagrams shown, each arrow represents a connection between two neurons and indicates the pathway for the flow of information. Each connection has a weight, an integer number that controls the signal between the two neurons.

If the network generates a “good or desired” output, there is no need to adjust the weights. However, if the network generates a “poor or undesired” output or an error, then the system alters the weights in order to improve subsequent results.

Machine Learning in ANNs

ANNs are capable of learning and they need to be trained. There are several learning strategies –

- **Supervised Learning** – It involves a teacher that is scholar than the ANN itself. For example, the teacher feeds some example data about which the teacher already knows the answers.
  For example, pattern recognizing. The ANN comes up with guesses while recognizing. Then the teacher provides the ANN with the answers. The network then compares its guesses with the teacher’s “correct” answers and makes adjustments according to errors.
- **Unsupervised Learning** – It is required when there is no example data set with known answers. For example, searching for a hidden pattern. In this case, clustering i.e. dividing a set of elements into groups according to some unknown pattern is carried out based on the existing data sets present.

- **Reinforcement Learning** – This strategy built on observation. The ANN makes a decision by observing its environment. If the observation is negative, the network adjusts its weights to be able to make a different required decision the next time.

Back Propagation Algorithm

It is the training or learning algorithm. It learns by example. If you submit to the algorithm the example of what you want the network to do, it changes the network's weights so that it can produce desired output for a particular input on finishing the training.

Back Propagation networks are ideal for simple Pattern Recognition and Mapping Tasks.

Bayesian Networks (BN)

These are the graphical structures used to represent the probabilistic relationship among a set of random variables. Bayesian networks are also called **Belief Networks** or **Bayes Nets.** BNs reason about an uncertain domain.

In these networks, each node represents a random variable with specific propositions. For example, in a medical diagnosis domain, the node Cancer represents the proposition that a patient has cancer.

The edges connecting the nodes represent probabilistic dependencies among those random variables. If out of two nodes, one is affecting the other then they must be directly connected in the directions of the effect. The strength of the relationship between variables is quantified by the probability associated with each node.

There is an only constraint on the arcs in a BN that you cannot return to a node simply by following directed arcs. Hence the BNs are called Directed Acyclic Graphs (DAGs).

BNs are capable of handling multivalued variables simultaneously. The BN variables are composed of two dimensions –

- Range of prepositions
- Probability assigned to each of the prepositions.

Consider a finite set $X = \{X_1, X_2, \ldots, X_n\}$ of discrete random variables, where each variable X_i may take values from a finite set, denoted by $Val(X_i)$. If there is a directed link from variable X_i to variable, X_j, then variable X_i will be a parent of variable X_j showing direct dependencies between the variables.

The structure of BN is ideal for combining prior knowledge and observed data. BN can be used to learn the causal relationships and understand various problem domains and to predict future events, even in case of missing data.

Building a Bayesian Network

A knowledge engineer can build a Bayesian network. There are a number of steps the knowledge engineer needs to take while building it.

Example problem – *Lung cancer.* A patient has been suffering from breathlessness. He visits the doctor, suspecting he has lung cancer. The doctor knows that barring lung cancer, there are various other possible diseases the patient might have such as tuberculosis and bronchitis.

Gather Relevant Information of Problem

- Is the patient a smoker? If yes, then high chances of cancer and bronchitis.
- Is the patient exposed to air pollution? If yes, what sort of air pollution?

- Taking an X-Ray positive X-ray would indicate either TB or lung cancer.

Identify Interesting Variables

The knowledge engineer tries to answer the questions –

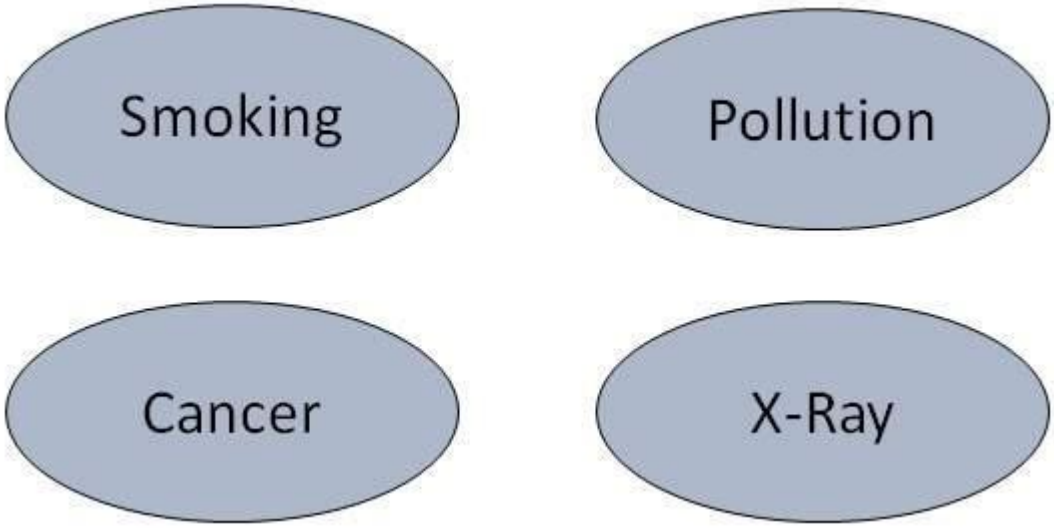
- Which nodes to represent?
- What values can they take? In which state can they be?

For now let us consider nodes, with only discrete values. The variable must take on exactly one of these values at a time.

Common types of discrete nodes are –

- **Boolean nodes** – They represent propositions, taking binary values TRUE (T) and FALSE (F).
- **Ordered values** – A node *Pollution* might represent and take values from {low, medium, high} describing degree of a patient's exposure to pollution.
- **Integral values** – A node called *Age* might represent patient's age with possible values from 1 to 120. Even at this early stage, modeling choices are being made.

Possible nodes and values for the lung cancer example –

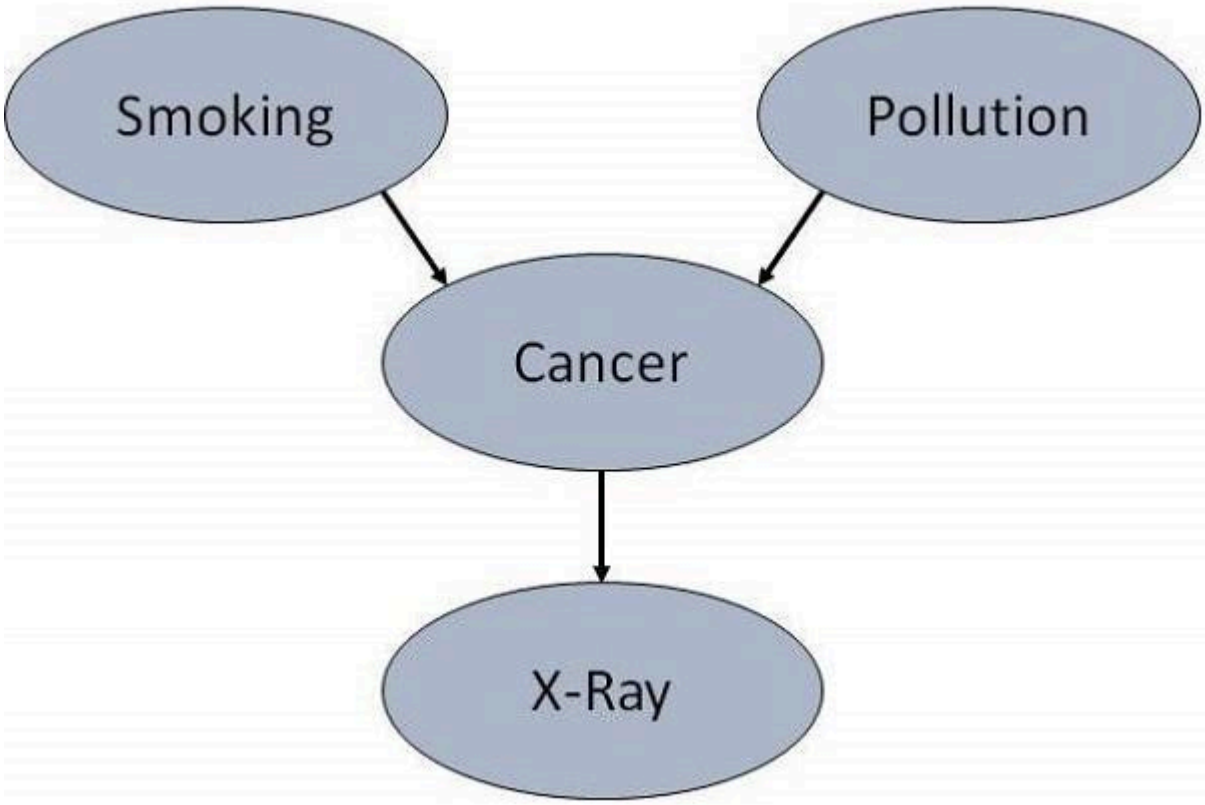
Node Name	Type	Value	Nodes Creation
Pollution	Binary	{LOW, HIGH, MEDIUM}	
Smoker	Boolean	{TRUE, FASLE}	
Lung-Cancer	Boolean	{TRUE, FASLE}	
X-Ray	Binary	{Positive, Negative}	

Create Arcs between Nodes

Topology of the network should capture qualitative relationships between variables.

For example, what causes a patient to have lung cancer? - Pollution and smoking. Then add arcs from node *Pollution* and node *Smoker* to node *Lung-Cancer.*

Similarly if a patient has lung cancer, then the X-ray result will be positive. Then add arcs from node *Lung-Cancer* to node *X-Ray.*



Specify Topology

Conventionally, BNs are laid out so that the arcs point from top to bottom. The set of parent nodes of a node X is given by Parents(X).

The *Lung-Cancer* node has two parents (reasons or causes): *Pollution* and *Smoker*, while node *Smoker* is an **ancestor** of node *X-Ray*. Similarly, *X-Ray* is a child (consequence or effects) of node *Lung-Cancer* and **successor** of nodes *Smoker* and *Pollution.*

Conditional Probabilities

Now quantify the relationships between connected nodes: this is done by specifying a conditional probability distribution for each node. As only discrete variables are considered here, this takes the form of a **Conditional Probability Table (CPT).**

First, for each node we need to look at all the possible combinations of values of those parent nodes. Each such combination is called an **instantiation** of the parent set. For each distinct instantiation of parent node values, we need to specify the probability that the child will take.

For example, the *Lung-Cancer* node's parents are *Pollution* and *Smoking.* They take the possible values = { (H,T), (H,F), (L,T), (L,F)}. The CPT specifies the probability of cancer for each of these cases as <0.05, 0.02, 0.03, 0.001> respectively.

Each node will have conditional probability associated as follows –

Smoking
P(S = T)
0.30

Pollution
P(P = L)
0.90

Lung-Cancer		
P	**S**	**P (C = T|P, S)**
H	T	0.05
H	F	0.02
L	T	0.03
L	F	0.001

X-Ray	
C	**X = (Pos | C)**
T	0.90
F	0.20

Applications of Neural Networks

They can perform tasks that are easy for a human but difficult for a machine –

- **Aerospace** – Autopilot aircrafts, aircraft fault detection.
- **Automotive** – Automobile guidance systems.
- **Military** – Weapon orientation and steering, target tracking, object discrimination, facial recognition, signal/image identification.
- **Electronics** – Code sequence prediction, IC chip layout, chip failure analysis, machine vision, voice synthesis.
- **Financial** – Real estate appraisal, loan advisor, mortgage screening, corporate bond rating, portfolio trading program, corporate financial analysis, currency value prediction, document readers, credit application evaluators.
- **Industrial** – Manufacturing process control, product design and analysis, quality inspection systems, welding quality analysis, paper quality prediction, chemical product design analysis, dynamic modeling of chemical process systems, machine maintenance analysis, project bidding, planning, and management.
- **Medical** – Cancer cell analysis, EEG and ECG analysis, prosthetic design, transplant time optimizer.
- **Speech** – Speech recognition, speech classification, text to speech conversion.
- **Telecommunications** – Image and data compression, automated information services, real-time spoken language translation.
- **Transportation** – Truck Brake system diagnosis, vehicle scheduling, routing systems.
- **Software** – Pattern Recognition in facial recognition, optical character recognition, etc.

- **Time Series Prediction** – ANNs are used to make predictions on stocks and natural calamities.
- **Signal Processing** – Neural networks can be trained to process an audio signal and filter it appropriately in the hearing aids.
- **Control** – ANNs are often used to make steering decisions of physical vehicles.
- **Anomaly Detection** – As ANNs are expert at recognizing patterns, they can also be trained to generate an output when something unusual occurs that misfits the pattern.

Genetic Learning:

Constraint satisfaction problem:

Propositional logic:

First order logic:

Semantic net:

Probable questions

Short questions (2mark each)

Section -A

Q1 (a) Define artificial intelligence.
(b) What are the four approaches for building AI?

(c) What is uninformed search?

(d) What is the Turing test?

(e) What is a knowledge base?

(f) What do you mean by the n-Queen problem?

(g) What are the applications of Artificial Intelligence ?

(h) What is the meaning of rational in AI?

(i)What is cognitive AI ?

(j) What is crypt arithmetic ?

2. (a).what is the difference between procedural knowledge and declarative knowledge?
(b) what is the difference between forward and backward reasoning?
(c) what do you mean by rote learning?
(d) Give an example of neural net learning?

(e) what do you mean by semantic network?
(f) what is non-monotonic logic?

(g) what do you mean by heuristic search?

(h) What is skolemization

Focused Type questions(each question carry 6 marks)

Section-B

Q.3. Write short note on (any four) (6 x 4)
(a) Inductive learning (b)Explanation based learning (c) Conceptual dependency
(d) production rule (e) knowledge Acquisition (f) Inference Engine

Q.4.(a) What is the difference between forward chaining and backward chaining ? Explain with suitable examples.

Q5. What do you mean by constraint satisfaction problem ? Explain with Water jug problem.
Q.6. Explain the n-queen problem .
Q7. (a)What is a Hill climbing search .Explain briefly?
(b)What do you mean by a heuristic search? Explain with an example.
Q.8. What is Means-ends analysis ? Explain with an Example.
Q.9. Short notes (any Two)
(a) Production System (b) Generate and Test © Best first Search

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Long type question(16 mark each)

Q.10. What do you mean by semantic network ? Explain thoroughly with suitable examples . Write down the advantages and disadvantages of semantic networks.

Q.11.What is a State Space ? State and explain with suitable examples. (16)

Q. 12. What is an Expert System ? State and explain the function of each component of the expert System with suitable examples.
Q.13. Explain alpha-beta pruning. Explain with suitable examples. Show game tree upto 3rd ply.

Q.14.Explain Min-Max search procedure. Explain it with example updo 3rd ply.

Q.15.Consider the following statement.

(a) Ravi owns a dog.

(b) Every dog owner is an animal lover.

(c) No animal lover kills an animal.

(d) Either Ravi or Smita kill the cat , who is named Tommy.

(e) Cat is an animal.

1. Translate into predicate logic format.
2. convert into clausal form.
3. Using resolution proves that Ravi killed the cat.